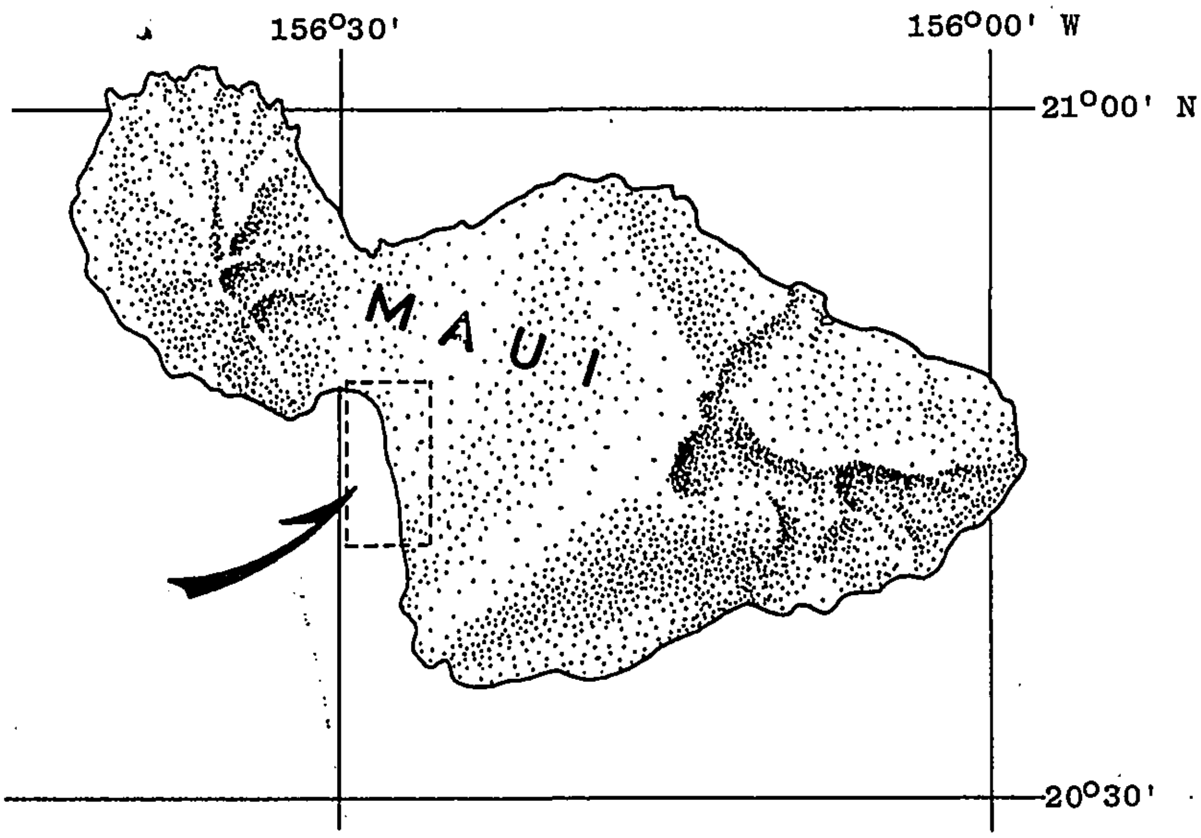
A RECONNAISSANCE SURVEY OF NEARSHORE MARINE ENVIRONMENTS AT KIHEI, MAUI



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U.S. Army Engineer Division
Pacific Ocean

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By

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PREFACE

Biological observations for the Kihei nearshore marine reconnaissance were made by Eric B. Guinther. Mr. Guinther, Joann Sinai, and George Krasnick analyzed the sediment samples. David Crear collected water samples and conducted water quality analyses. The algae collections were identified by Dennis Russell. Kristine Cushing produced the maps. The final report was prepared by the project manager at ECI, Eric Guinther.

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INTRODUCTION

The Kihei Floodplain of east Maui is undergoing rapid urbanization with the construction of housing, condominiums, hotels, and supportive facilities. Urbanization is presently concentrated along the coast in a one-half mile wide corridor beween Keahuaiwi Gulch in the north and Wailea in the south (a distance of about 12 kilometers or 7 miles; see Fig. 1). The climate in the coastal belt is dry, and stream channels (gulches) crossing the floodplain from upslope (Haleakala) carry water only intermitantly. Serious flood discharges, although infrequent (see Ewart, 1971; Maciolek, 1971), are a matter of concern. Modifications to the existing drainage patterns through the Kihei Floodplain have been proposed (Sam Hirota, Inc., 1977).

The present report details the results of a marine reconnaissance survey conducted for the U.S. Army Corps of Engineers under contract DACW84-77-C-0034 (Modification P00003). The objective of the survey is to provide baseline data on the nature of the inshore marine environment in the proximity of four stream mouths or proposed channel alignments. The results are directed towards evaluating present effects of stream discharge on the environment and assessing potential impacts of stream channel modifications.

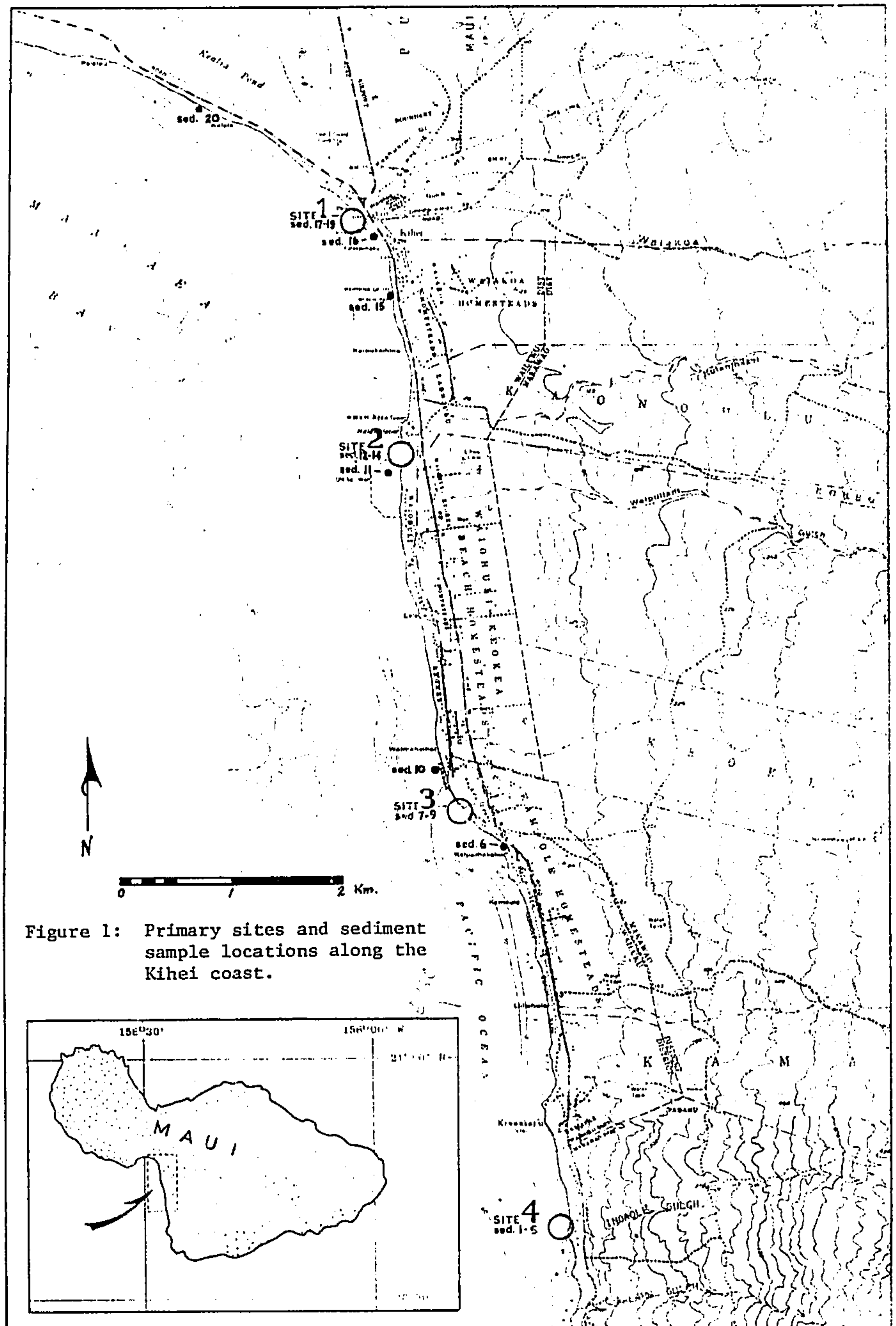

Figure 1: Primary sites and sediment sample locations along the Kihei coast.

METHODS

The field survey encompassed the immediate offshore environment adjacent to the mouths of four potential channel alignments for the flood control project. The sites surveyed were:

Site 1 - Waiakoa Gulch entrance into nearshore ocean waters

Site 2 - proposed channel alignment between Kalepolepo and Waipuilani Gulch

Site 3 - Kalama Park in the vicinity of an unnamed drainage canal

Site 4 - Keawakapu Beach Park immediately offshore of Inoaole Gulch

Water quality data (salinity, turbidity, and dissolved nutrients), sediment samples, and biological observations were obtained from each of these primary sites during the period of August 19-21, 1977. Supplemental information (biological observation, sediment sample, and/or turbidity measurement) was collected from Kaleia (shoreline of Maalaea Bay fronting Kealia Pond), Kihei Pier, the beach park at Maipoina oe iau, the fish pond (relict) seaward of the mouth of Waipuilani Gulch, and the nearshore environment at the northern and southern boundaries of Kalama Park.

WATER QUALITY

Water samples for turbidity analyses were taken in 30 ml, amber polyethylene bottles and preserved in the field with two drops of a 2.5 g/l HgCl solution (producing a sample concentration of approximately 10 mg HgCl/l). These samples were stored in a refrigerator upon returning from the field until analyses commenced. Samples for turbidity analyses were taken during light wind conditions (i.e., in the morning when wind speed was under 10 mph) and during stronger wind conditions (i.e., in the afternoon when wind speed was greater than 10 mph). All turbidity data collected are shown in Appendix A. Water samples for nutrient analyses were taken in 250 ml, amber, polyethylene bottles. These bottles were held at ambient temperature while in transit and frozen after returning from the field. Nutrient data are given in Appendix B. All water samples were collected by a swimmer. Turbidity samples were collected at distances of approximately 50 and 100 meters from the shoreline; nutrient samples were taken at a distance of 100 meters from the shoreline.

Turbidity analyses were performed on a Turner Model 111 fluorometer using the nephelometric method as outlined in Standard Methods (1976). The fluorometer was equipped with a Corning CS7-60 primary filter and a 110-823L secondary filter (ten percent transmittance, neutral density type). Turbidity concentrations were determined against freshly prepared formazin standards as outlined in Standard Methods (1976). Data are reported in FTU (Formain Turbidity Units). All turbidity analyses were completed within three days after collection.

Concentrations of soluble, inorganic nutrients were determined for ammonia, nitrite plus nitrate, and orthophosphate. Ammonia analyses were performed using the method of Liddicoat, *et al.* (1975). The method is a phenol-hypochlorite reaction utilizing an ultraviolet light for optimum color development. Nitrite plus nitrate concentrations were determined as outlined in Strickland and Parsons (1972) by measuring the concentration of nitrite after passing the samples through a cadmium reduction column. The cadmium fillings were prepared as outlined by Strickland and Parsons and conditioned by passing 6 liters of a strong nitrate solution (about 60 ug-at N/1) through each column. Phosphate phosphorous was analyzed according to a procedure utilizing a phosphomolybdate complex as outlined in Strickland and Parsons (1972). All nutrient samples were filtered though a 4.25 cm GF/C glass fiber filter immediately before commencing nutrient analyses. Extinction values were measured on a Coleman Model 111, spectrophotometer equipped with a

Bio-Tech Model 450 digital readout. All nutrient analyses were completed within six days of the collection of water samples.

Salinity measurements were made in the field with an American Optics hand-held refractometer. Salinities were confirmed by taking refractometer readings of the water samples collected for turbidity determinations.

SEDIMENT SAMPLES

Twenty sediment samples were collected between Kealia in the north and Keawakapu in the south (see Fig. 1). Approximately 200 cc. of sediment was collected at each site by carefully inserting a glass jar into the substratum. After a jar was filled with bottom material, it was capped to prevent washing-out of the silt fraction as the sample was brought to the water surface. The sample was then transferred to a numbered plastic bag, and returned to Honolulu for processing.

In the laboratory, each sample was washed with tap water over a 0.125 mm (3.0 *phi*) mesh screen. Wash water containing the very fine sand and silt fractions was collected in a beaker and allowed to stand for 2 hours, following which time excess water was decanted off and the settled fractions added to a preweighed dish for drying in an oven set an 40-50 °C. The washed samples (fractions $>$ 0.125 mm) were placed in aluminum pans in the same oven, and all samples were dried for 24 to 48 hours.

After drying, the sample was placed in the uppermost sieve of a graded series (representing 1.0 *phi* intervals) and shaken by hand. The fraction retained in each sieve was then weighed on a Mettler top-loading balance. Sediments passing through the finest mesh (0.125 mm) were added to and weighed with the fines initially washed from the sample.

The percent calcium carbonate of the sand samples was determined by a volumetric technique outlined in Carver (1971). The apparatus used is shown in Figure 2. A 0.5 gm. sample, hand-ground in a mortar, is combined with concentrated hydrochloric acid in the reaction chamber and the CO_2 gas thus generated displaces a volume of fluid directly proportional to the quantity of carbonate in the sample. The technique was standardized against reagent grade calcium carbonate. The results reported (see Appendix D) assume all the carbonate occurs as calcium carbonate. The percent of each fraction which is not calcium carbonate is assumed to be organic matter and terrigenous (igneous) sedimentary material. In most samples, and particularly those containing a small amount of silt in the pan fraction, the proportion which is not calcium carbonate is predominantly volcanic in origin.

BIOLOGICAL SURVEYS

Initially it was planned to conduct quadrat counts of macrofauna and macroflora along several transects at each of the primary sites. However, at sites 2 and 3 turbid nearshore conditions and (during the afternoons) wind waves coming onshore made it impossible to conduct accurate counts of benthic organisms, or to observe reef fishes. For example, horizontal visibility in the water within 50 meters of shore at Kalama Park was estimated to be 60 cm. for a bright-white object (the arms of a PVC quadrat square). The bottom could not be seen from distances exceeding 30 cm. in most areas, and in some areas of silty sand, the bottom simply could not be seen at all. These conditions imposed obvious restrictions on the collection of quantitative data, restrictions which varied from site to site. The use of identical survey methods at each site would not have produced comparable results. Consequently, survey methods were adjusted at each location in order to achieve the goals set out in the scope of work.

At all sites the biological survey was begun with a general reconnaissance of the area. Beginning at the shoreline opposite the entrance of the

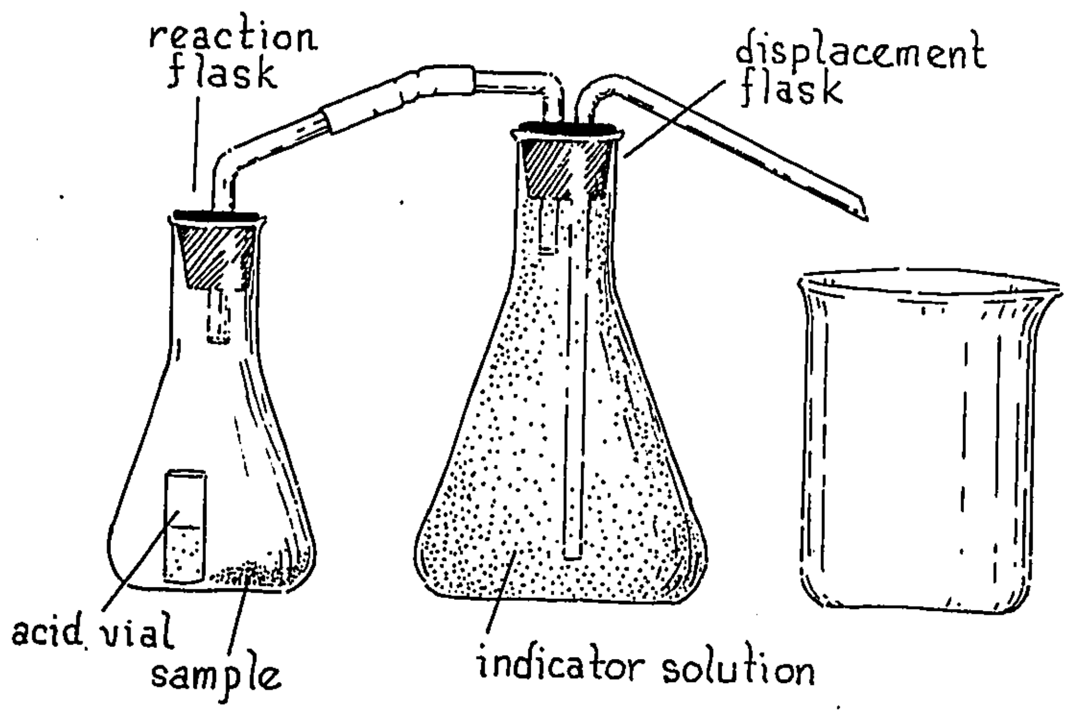

Figure 2: Apparatus for gasometric determination of $CaCO_3$ content. When all stoppers are tightly fitted, the reaction flask is tipped so as to release acid onto the sample. The volume of CO_2 gas generated is measured as the volume of indicator solution displaced into the beaker.

gulch or proposed channel alignment, a diver traversed a zig-zag course, gradually moving offshore. Notes on benthic organisms, fishes, and the nature of the bottom were recorded on underwater slates. This process was continued until the nearest occurrences of living coral heads was determined and, either a distance of 150 meters offshore was reached, or bottom depth exceeded 10 meters. In fact, reconnaissance always extended to 150 meters offshore.

At Site 1 (Kihei/Waiakoa Gulch) only a qualitative assessment of the benthic biota and fishes was undertaken because reconnaissance revealed the bottom to be predominantly sand well beyond 200 meters from shore. Isolated occurrences of basalt boulders were inspected and the biota associated with these recorded.

At Site 2 (between Kalepolepo and Waipuilani Gulch), four transect lines, each 50 meters in length, were laid out perpendicular to the shore. The base of each line was anchored in the intertidal (littoral) zone. The type of bottom (i.e., sand, rubble, boulder, etc.) was determined under each of the meter marks on the line. Abundance of foliose algae was assessed in two quadrats (one meter on a side) placed along each transect line. The quadrat positions were stratified, a randomly selected number determining one position in the inner segment (first 25 meters) and one in the outer segment (second 25 meters) of the transect. All of the foliose algae in a quadrat were gathered and placed in a numbered plastic bag. In the laboratory, the algae were sorted by species, dried in an oven set at 40-50 ^{o}C until crisp (24-48 hours) and weighed on a Mettler (P-163) top-loading balance. Data on benthic fauna and fishes were obtained during reconnaissance swims.

Methods applied at Site 3 (Kalama Park) were essentially identical to those used at Site 2 except that a total of three transect lines were laid. At Site 4 (Keawekapu Beach Park) reconnaissance revealed a sand bottom extending out well beyond 200 meters in the central and northern areas, and a basalt ridge or spur extending as a submarine feature from a low rocky headland south of the outlet of Inoaole Gulch. Two transect lines were established across this spur, each 20 meters in length and oriented roughly parallel with the shoreline. Bottom type was determined by the point-intercept method along each line. In addition, cover by live coral heads, bottom type, and enumeration of sea urchins were undertaken in one-meter square quadrats along the transect lines. Bottom cover, expressed as percent, was estimated by counting the number of 10 by 10 cm. squares, out of 100 in the quadrat frame, over half-filled by a particular bottom type. Transects were not established directly offshore of the gulch or to the north of the gulch as these would have traversed 100% sand bottom.

RESULTS

WATER QUALITY

The mean values for the turbidity analyses are shown in Table 1. Mean results for the nutrient analyses, total inorganic nitrogen concentrations, and the N:P ratios (by atoms) in the water samples are shown in Table 2. The salinity was measured at 35 $^{o}/oo$ at all stations except Site 2 where a salinity of 33 $^{o}/oo$ was found both at the shoreline and 100 meters offshore.

PHYSIOGRAPHY OF THE SURVEY SITES

Site 1 (Kihei/Waiakoa Gulch; Fig. 3): Waiakoa Gulch is a shallow depression passing through a box culvert under the Kihei Road and terminating behind the beach in a shallow, sand-bottom pond overgrown with grasses. Several condominiums line the coastline here, and the pond is located in a narrow accessway between two buildings. Between 30 and 40 meters of sand beach separates the pond from the ocean. The beach sand is composed predominantly of fine grains (sediment sample 17; see Table 3 and Fig. 4), 73% by weight calcium carbonate.

Offshore, the beach is continuous with a sand deposit on a gently sloping bottom which continues out beyond 200 meters of shore and a depth of 10 meters. A coral reef is not present offshore. Sand in the submarine deposit (samples 18 and 19) is finer-grained than the beach sand, and contains less calcium carbonate (55-56%). Curiously, sand (sample 16) from 25 meters offshore east of Kihei Pier (relict) has a grain size composition more nearly like that of the beach than offshore sediments fronting Waiakoa Gulch. The amount of calcium carbonate (61%) lies between values obtained for beach and submarine deposits off Waiakoa Gulch outlet. Basalt boulders occur scattered over the sand bottom. Boulders were particularly numerous directly seaward of Waiakoa Gulch, and at this point can be found within 10 meters of the shoreline.

Table 1: Mean turbidity values for water samples from Kihei, Maui, August 20-21, 1977.

Site	Morning Sampling (FTU)	Afternoon Sampling (FTU)	$\bar{x}$
1	0.40	0.32	0.36
2	1.07	0.62	0.85
3	1.31	2.06	1.69
4	0.35	0.28	0.32
$\bar{x}$	0.78	0.82	

Site	Distance from Shore 50 m	100 m	$\bar{x}$
1	0.34	0.38	0.36
2	0.91	0.78	0.84
3	2.15	1.22	1.68
4	0.34	0.29	0.31
$\bar{x}$	0.94	0.67	

Table 2 : Mean nutrient concentrations, total inorganic nitrogen values, and N:P ratios for water samples from Kihei, Maui, August 20-21, 1977.

Site	NH_3-N (µg-at/l)	NO_2+NO_3-N (µg-at/l)	PO_4-P (µg-at/l)	Total Inorganic Nitrogen (µg-at/l)	N:P
1	0.46	2.65	0.15	3.11	20.7
2	0.46	5.41	0.27	5.87	21.7
3	0.40	0.53	0.11	0.93	8.4
4	0.37	0.39	0.15	0.76	5.1

Table 3: Mean grain size (in *phi* units) and standard deviations for the sediment samples collected from the Kihei, Maui area.

Sample	$\bar{x}_\phi$	S.D.$_\phi$
1	2.6	0.4
2	2.7	0.7
3	2.6	0.4
4	2.1	0.5
5	2.5	0.3
6	2.6	0.5
7	2.2	0.5
8	2.1	1.1
9	2.4	0.4
10	2.4	0.4
11	3.1	0.6
12	2.4	0.8
13	3.0	0.7
14	1.3	1.5
15	3.1	1.0
16	2.8	0.7
17	2.1	0.8
18	3.1	0.5
19	3.2	0.5
20	2.8	0.3

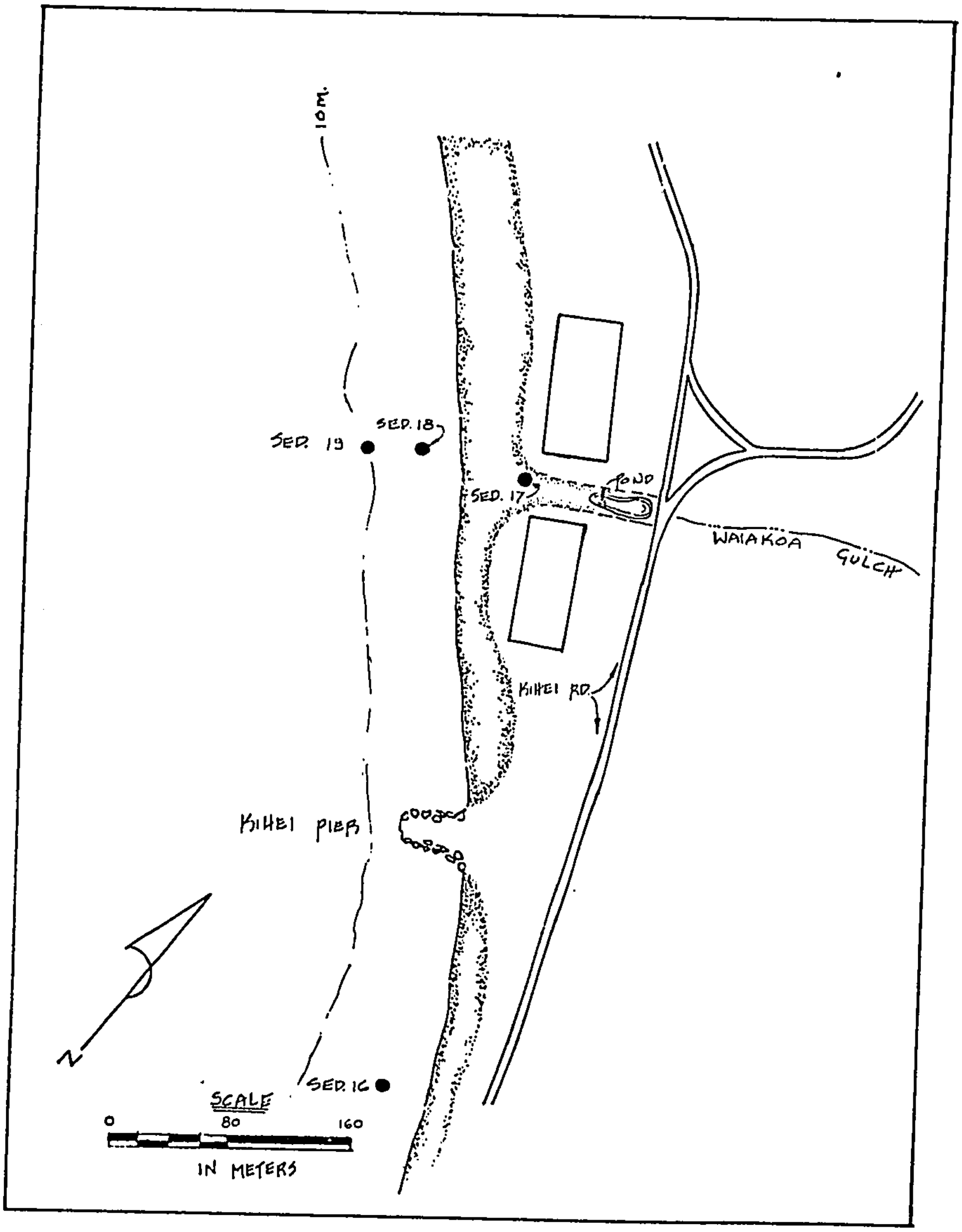

Figure 3: Site 1 map with location of sediment samples.

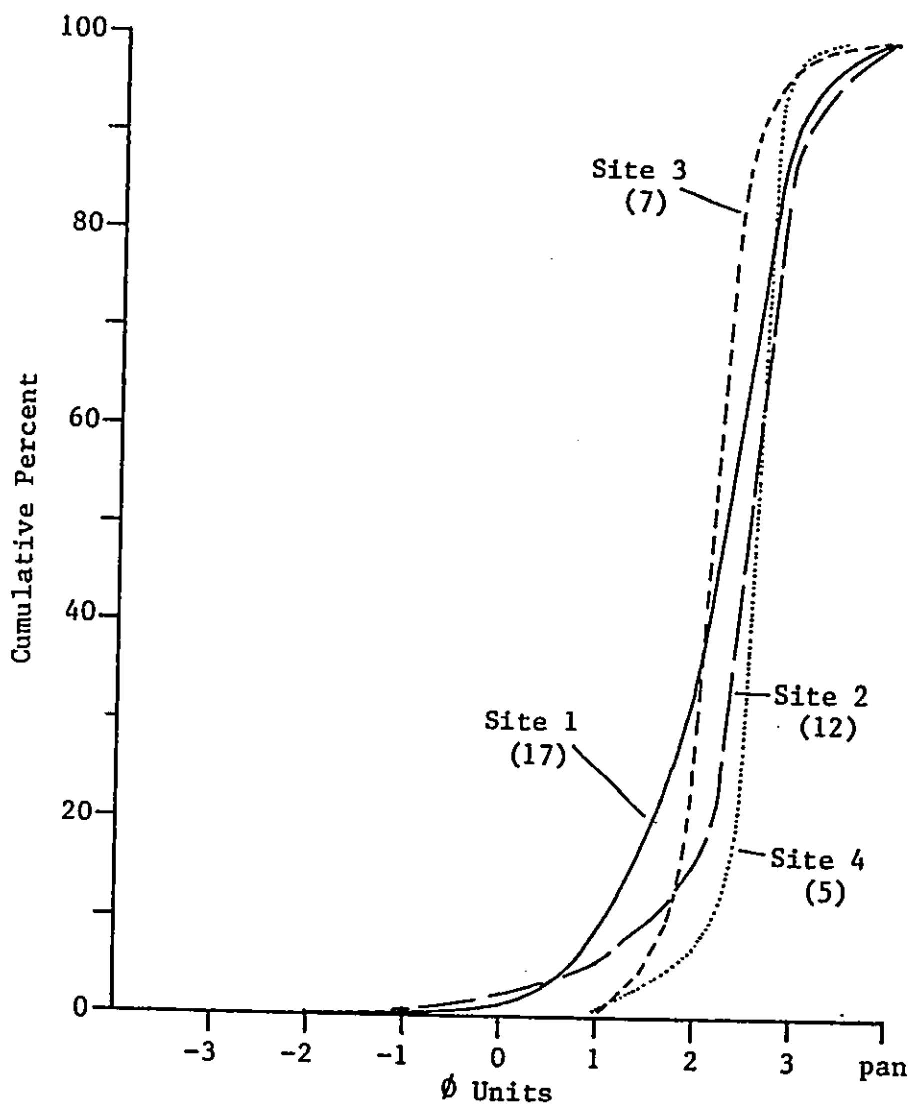

Figure 4: Comparison of cumulative frequency curves for beach samples in the Kihei area.

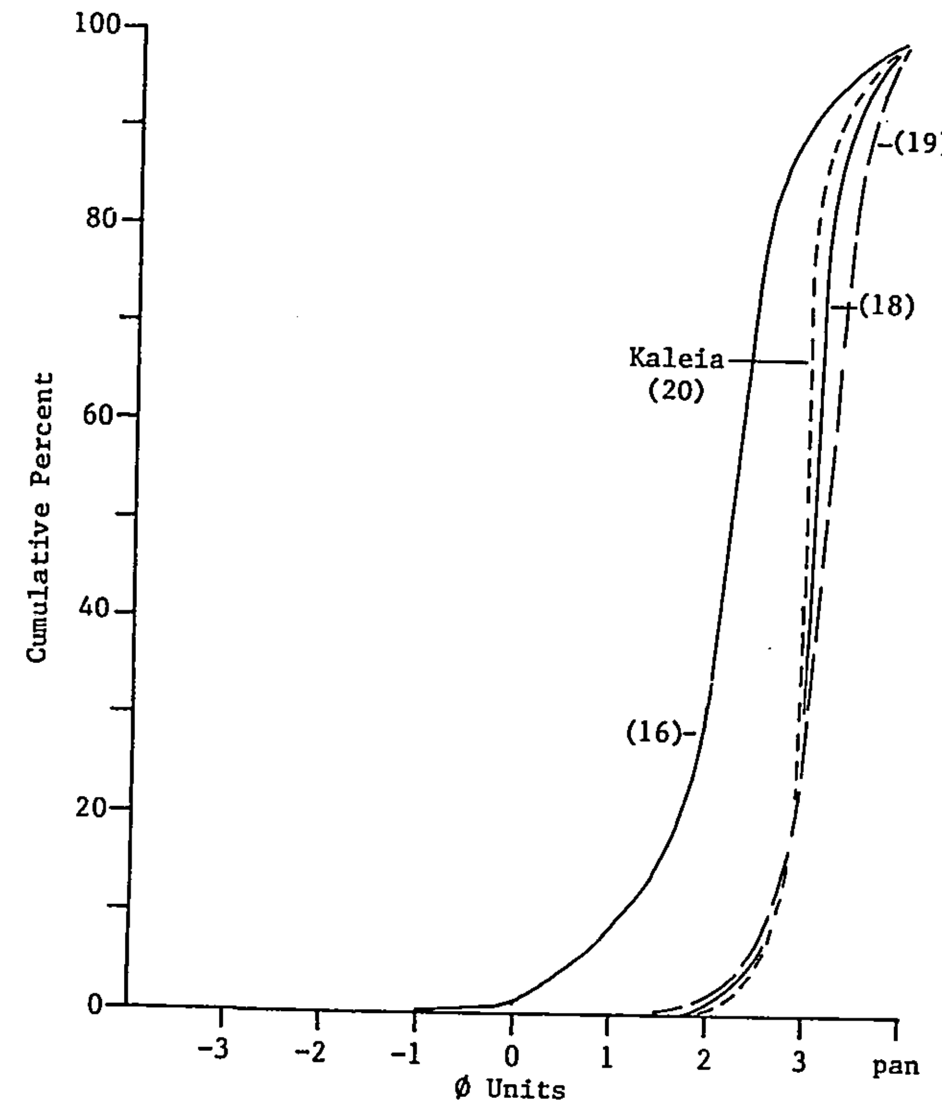

Figure 5: Comparison of cumulative frequency curves of offshore sediments collected between Kaleia and Kihei Pier.

The only occurrence of hard substratum at the shoreline are the basalt boulders of Kihei Pier.

Site 2 (Kalepolepo, fishpond, and Waipuilani Gulch; Fig. 6): A small, unnamed drainage basin landward of Kihei Road terminates behind the beach in a pond adjacent to the highway. A box culvert connects this pond with the drainage basin. Some 50 meters of beach sand separates the pond from the ocean. At the beach crest (sample 12), this sand is extremely well sorted and fine-grained. Calcium carbonate makes up 75% of this sand, by weight. As at Site 1, the ocean beach fronting the pond has build up in a manner commensurate with adjacent areas, leaving no topographic evidence of stream flow into Maalaea Bay. No evidence of scouring or deposition attributable to land drainage is apparent on the nearshore reef flat, although the offshore sand deposit continuous with the beach is narrower opposite the pond than to the north or south (see Table 4).

Seaward of the beach the bottom extends out as a shallow reef platform, and at 200 meters from shore depth does not exceed 1.5 meters. The beach deposit opposite the pond terminates between 10 and 15 meters of shore (transect A), thereafter the reef flat has a predominantly rubble bottom with sand occurring in patchy, thin layers over the rubble. South of the pond, adjacent to the fishpond wall, sand bottom is more or less continuous out to 50 meters (transect A(S)). Some 40 meters north of transect A is a field of basalt boulders extending from the lower beach to about 10 meters offshore. Thereafter, sand bottom predominates (with scattered patches of rubble and larger boulders) out to around 30 meters from shore (transect A(N)).

Sand from the sublittoral deposit at the shoreline (sample 13) resembles generally that found on the beach (sample 12), although mean grain-size is smaller. The difference may be accounted for by wind erosion removing the fine fractions from the dry beach. As at Site 1, sand on the beach has a much

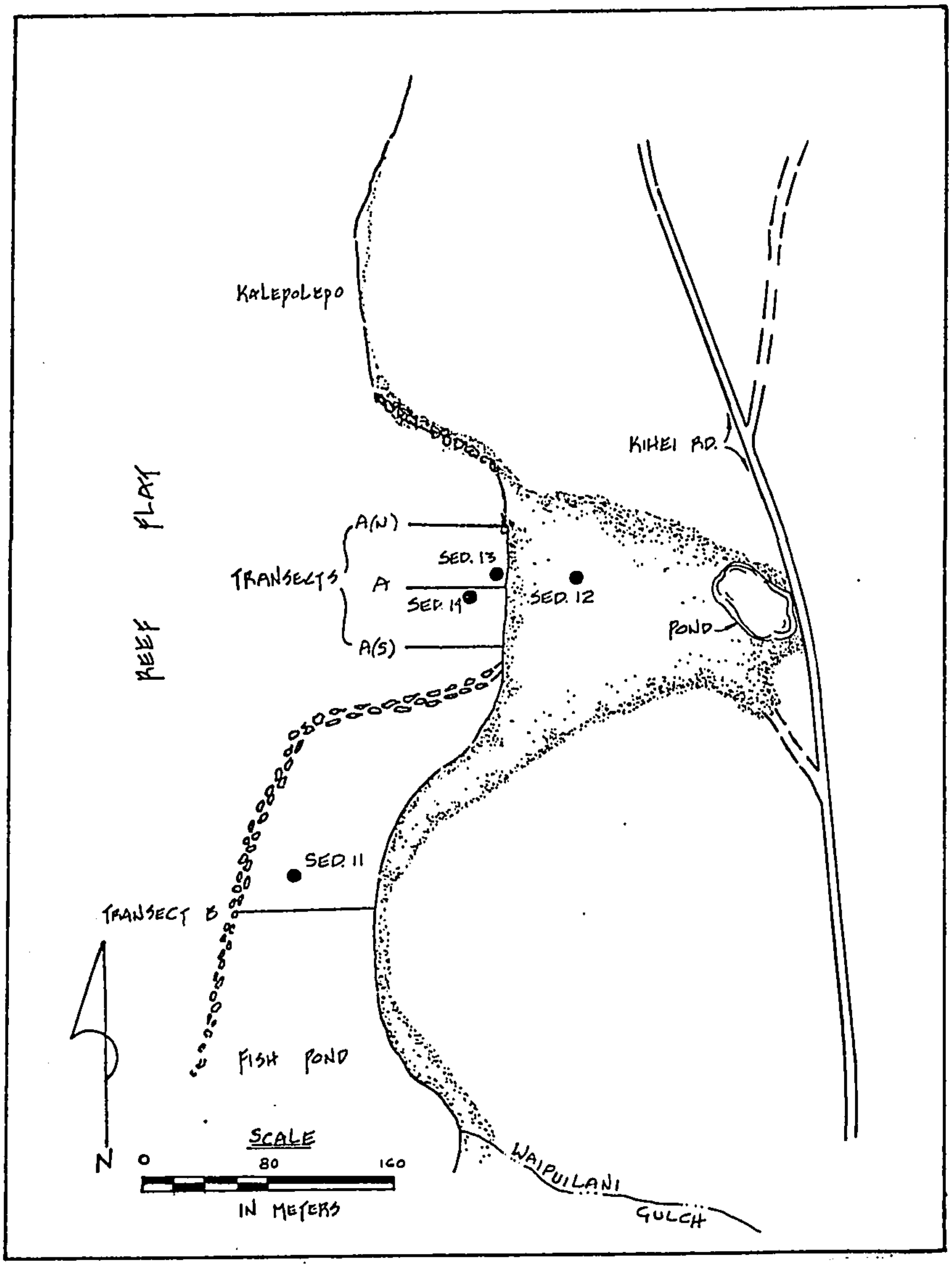

Figure 6: Site 2 map with location of sediment samples and transects.

Table 4: Results and summary of point-quadrat determinations of bottom type at Site 2.

TRANSECT DATA

	B		A(S)		A		A(N)
FISHPOND WALL	bB	REEF FLAT	S	REEF FLAT	R	REEF FLAT	So/s
	bB		S		R/s		So/s
	bB		S		B/s		R
	bB		S		R/s		S
	bB		S		So		S
	bB		S		S		R/s
	bB		S		S		So/s
	bB		S		S		So/s
	bB		R/s		S		S
	bB		S		B		S
FISHPOND	S		S		R/s		S
	S		S		R/s		S
	S		S		R/s		S
	S		S		R/s		S
	S		S		R/s		S
	S		S		R/s		S
	S		S		R		S
	S		S		S		S
	S		S		R		S
	S		S		R		S
	S		S		B		S
	S		S		S		S
	S		S		S		S
	S		S		R/s		S
	S		S		R/s		B
	S		S		R/s		S
	S		S		S		S
	S		S		R/s		S
	S		S		R/s		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S	BEACH	bB
	S		S		S		bB
	S		S		S		bB
	S		S		S		bB
	S	BEACH	S	BEACH	S		bB
	S		S		S		bB
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S
	S		S		S		S

PERCENT BOTTOM TYPE ON REEF FLAT (EXCLUDES BEACH AND FISHPOND)

	transect A(S)	A	A(N)	combined	
Silt (Si)	0	0	0	0	%
Sand (S)	98	50	75	74	
Rubble(R,R/s)	2	41	5	16	
Boulder (B,B/s)	0	7	10	6	
Consolidated reef (So,So/s)	0	2	10	4	

R/s, B/s. So/s represent thin deposits of sand over rubble, boulder, or consolidated reef limestone.

bB represents basalt boulders

higher calcium carbonate content (75%) than the subbeach sand (54%). Sand from the reef flat (sample 14; see Table 3) is different in character from that comprising the beach and its nearshore submarine deposit. This sand occurs in thin patches and runnels, is poorly sorted, and considerably coarser than the beach sand. Not surprising, in view of its make-up of coral, coralline algae, and mollusc fragments, the calcium carbonate content is high (81%).

The fishpond surrounding the outlet of Waipuilani Gulch is less than one meter deep, and has a flat bottom. Deposition of sand has completely covered any occurrences of limestone rubble or boulders inside the pond. The sand here (sample 11) is fine-grained, and closely resembles sand found subtidally fronting the beach (sample 13), although its calcium carbonate content is higher (62% by weight compared with 54% in sample 13). The poor condition of the seaward walls has apparently prevented an excessive accumulation of silt in the fishpond. The walls are composed of basalt boulders only slightly emergent at low tide.

<u>Site 3 (Kalama Park; Fig. 7)</u>: An unnamed water course, lined with massive basalt basalt boulders forming a trapezoid-shaped culvert, crosses the middle of Kalama Park. This culvert is some 30 meters wide and has a sand bottom. The massive boulders continue north and south of the culvert outlet, forming a seawall over 2 meters high fronting the shoreline of the park. The only beach in the park is the sand deposit formed across the mouth of the culvert, although a submerged sand deposit of variable width extends along the base of the seawall. One hundred meters inland from the beach at the mouth of the culvert is a shallow pond.

Seaward of the park is a broad reef flat comparable to that found at Site 2. It would appear from comparison of the point-intercept results of bottom type (Table 5) that this reef flat is covered with more limestone rubble than at Site 2 (at least within 50 meters of shore). In the immediate vicinity

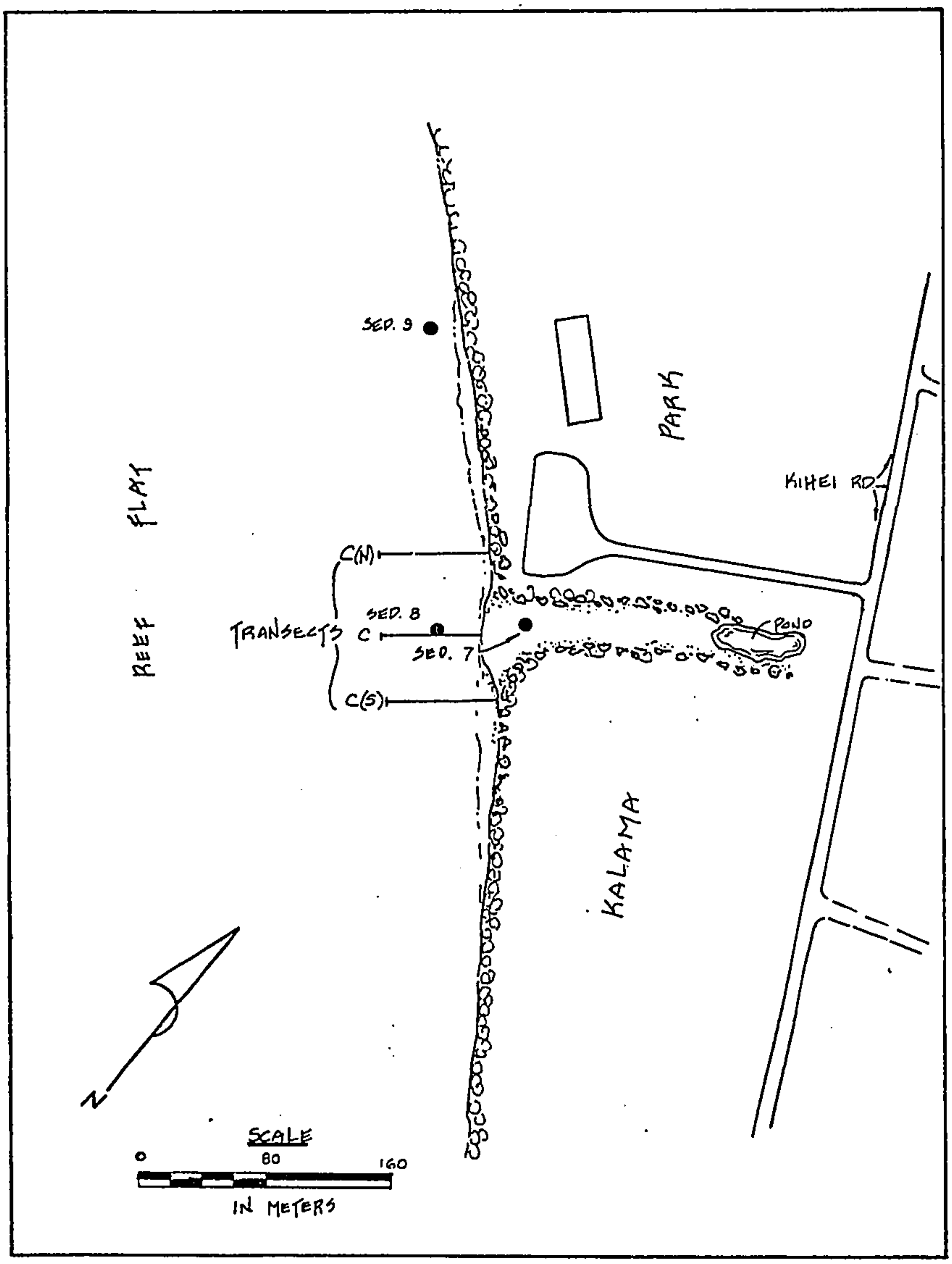

Figure 7: Site 3 map with location of sediment samples and transects.

Table 5: Results and summary of point-quadrat determinations of bottom type at Site 3 (Kalama Park).

TRANSECT DATA

C(S)	C	C(N)
So/s	R/s	R
S	So/s	R
R/s	R/s	S
R/s	S	R/s
So/s	S	So
So/s	R/s	R/s
So/s	R/s	So
So/s	S	S
S	R/s	B
S	S	B
R/s	S	R/s
S	R/s	B
B	R/s	R/s
R/s	S	R/s
So/s	So	R/s
R/s	S	R/s
So/s	S	B
So/s	S	R/s
So/s	R	R/s
R/s	S	R/s
S	R/s	R/si
R/s	R	R/si
R/s	R	R/si
R/s	S	R/si
R/s	R	R/si
R/s	R	R/si
R/s	R	R/si
R/s	S	Si
S	S	Si
R/s	S	Si
So/s	S	Si
S	S	Si
So	S	Si
R/s	S	Si
So/s	S	Si
So/s	S	Si
S	S	Si
S	S	Si
S	S	S
S	R	R/s
S	R	S
S	S	S
S	R	S
S	R	S
S	R	S
S	R	S
S	S	S
S	S	S
bB	S	R/s
bB	S	bB

C(S): REEF FLAT; SEAWALL (bB). C: REEF FLAT; BEACH. C(N): REEF FLAT; SEAWALL (bB).

PERCENT BOTTOM TYPE ON REEF FLAT (EXCLUDES BEACH AND SEAWALL):

	Transect C(S)	Transect C	Transect C(N)	combined	
Silt (Si)	0	0	22	8	%
Sand (S)	40	53	23	38	
Rubble (R,R/s)	31	43	43	40	
Boulder (B,B/s)	2	0	8	4	
Consolidated reef (So,So/s)	27	4	4	10	

R/s, B/s, So/s represent thin deposits of sand over rubble, boulder, or consolidated limestone.

bB represents basalt boulders of the seawall.

of the culvert outlet (transect C) the reef flat is somewhat shallower (by 30 to 50 cm.) than at comparable distances from shore on transects C(S) or C(N). Transect C(N) crosses a large patch of silt beginning 12 meters offshore of the seawall (see Table 5). This silt is grey in color (black beneath the surface owing to reducing conditions) and forms a layer 10 to 20 cm. deep. In the vicinity of this deposit water clarity was the poorest encountered during the survey.

The sand deposit presently blocking the mouth of the drainage culvert (sample 7) is remarkably well sorted (Fig. 4). This sand is somewhat coarser than that found on the beach at Sites 2 and 4. Sand from directly offshore of the beach (sample 8) is less well sorted, containing a greater proportion of both finer and coarser grains than the beach sand. Both samples are 84% calcium carbonate by weight.

Site 4 (Keawakapu Beach Park/Inoaole Gulch; Fig. 8): Keawakapu Beach is the landward terminus of an extensive sand deposit extending into deep water. The beach is formed into a nearly 3-meter high berm which covers the mouth of Inoaole Gulch. There is presently no water trapped behind this berm. The sand deposit offshore drops steadily into deeper water, so that at 200 meters from the beach sand bottom is present at a depth of over 10 meters. No coral reef occurs offshore. Sand on the beach (sample 5) is slightly better sorted than the beach sand at Site 3, although mean grain size is smaller. Sand in the intertidal zone (sample 3) and sand from 50 meters offshore (sample 1) are similar to that on the beach, with a somewhat higher proportion of very fine sand grains and silt. At 100 meters offshore (sample 2) sorting is somewhat poorer and the proportion of very fine sand and silt is greater still. All five sand samples obtained at Site 4 contain 80% or more calcium carbonate by weight.

Directly south of the outlet of Inoaole Gulch is a low rocky headland

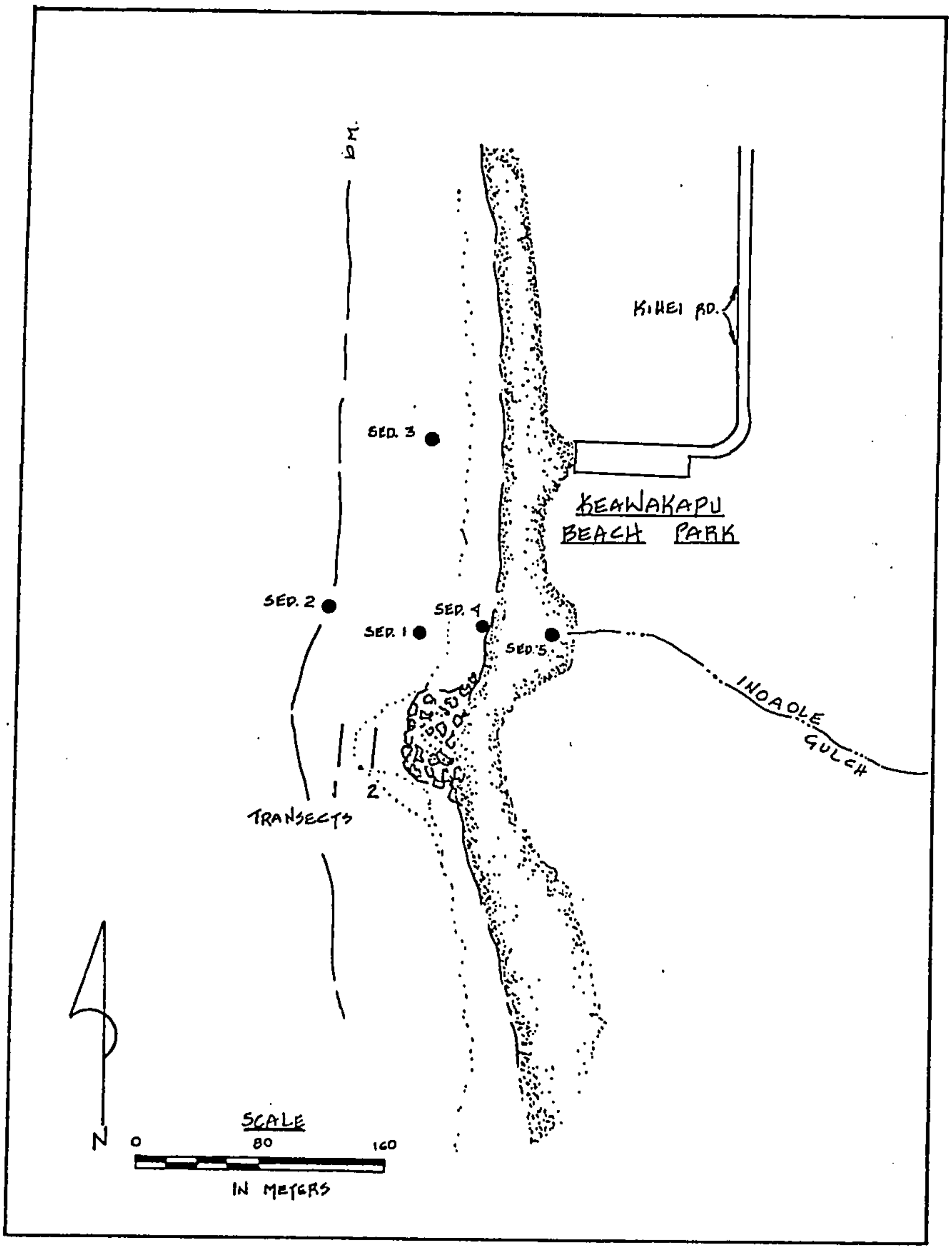

Figure 8: Site 4 map with location of sediment samples.

which extends offshore as a submarine basalt spur harboring corals and echinoderms. The northern face of this spur, at least nearshore, is steep-sided, although no topographic evidence of a channel is apparent in the sand bottom adjacent to this submarine cliff which is directly offshore of the mouth of Inoaole Gulch. The poorest water clarity off Keawakapu Beach was associated with the inshore, northern margin of the spur. Comparison of the two sediment samples collected 50 meters off the beach (Table 3), one (sample 1) from adjacent to the spur, and the other (sample 3) from approximately 100 meters to the north, shows a greater proportion of very fine sand and silt on the bottom near the spur. This circumstance is probably related to slowing down of silt-transporting longshore currents as the spur is approached rather than to deposition related to Inoaole Gulch.

BIOLOGICAL OBSERVATIONS

Site 1 (Kihei/Waiakoa Gulch): The pond at the seaward terminus of Waiakoa Gulch is heavily overgrown with introduced grasses. Water in this pond registered fresh (i.e., < 0.25 ‰) by refractometer on August 20. Numerous small poecillid fish (?*Gambusia*) and 4 to 6 inch long mullet (probably *Mugil cephalus*) live in the pond, although the mullet appeared diseased.

The offshore environment is an extensive sand deposit without macrofauna in evidence. Basalt boulders scattered over this bottom harbor short-spined sea urchins (*Tripneustes gratilla*), but no macrothallic algae. In areas of basalt boulders and rubble-forming patches from a few square meters to a square decimeter, the density of *T. gratilla* was estimated at between 10 and 15 individuals per m^2. Test diameter of nearly all of the *Tripneustes* seen was 5 to 6 cm., about half the size normally attained by this species. Occasionally seen on these boulders are colonial hydrozoans (*Halocordyle disticha*), long-spined urchins (*Echinothrix calamaris*), and small anemones. One fist-size head of an upright-growing bryozoan (*Schizoporella unicornis*) was observed. Some boulders close to shore are completely covered with a small mussel (*Hormomya crebristriatus*).

Several opelu (*Decapterus macarellus*) were seen in the water above sand bottom, but the few other fish observed were always associated with the relief afforded by basalt boulders, and in one place, a degraded automobile body. These fish included maomao (*Abudefduf abdominalis*), manini (*Acanthurus triostegis sandvicensis*), *Dascyllus albisella*, *Chaetodon miliaris*, and *Acanthurus* sp. The most common species associated with larger basalt boulders is the snapper, *Lutjanus kasmira*.

A dense growth of littoral and sublittoral algae occurs on the basalt boulders of the Kihei Pier. Species present include *Ahnfeltia concinna*, *Ulva fasciata*, and a deep-red rhodophyte.

<u>Site 2 (Kalepolepo to outlet of Waipuilani Gulch)</u>. The shallow pond adjacent to Kihei Road contained water at a salinity of 40 $^{o}/oo$ on August 20. The water was turbid green in color. A few small fish (?*Gambusia*) were observed in the pond.

The area seaward of Kalepolepo and the fishpond at the outlet of Waipuilani Gulch is a shallow reef platform extending several hundred meters offshore. Reconnaissance of this reef revealed isolated heads of living coral about 100 meters from the beach. These heads were mostly *Porites lobata*, although one head of *Porites evermanni* was seen. Several of the *P. lobata* heads had been recently damaged on their upper surfaces, as if scraped by an anchor or boat. Soft corals (Zoanthidae: *Palythoa tuberculosa* and *Zoanthus pacificus*) and the urchin, *Echinometra mathaei*, are common on the reef flat. Some boulders near shore are covered with great numbers of the attached mussel, *Hormomya crebristriatus*. The alcyonarian, *Anthelia edmondsoni*, is abundant just seaward of the fishpond wall. Small heads of *Pocillopora damicornis*, attached to basalt boulders on the inner and outer margins of the fishpond wall, constitute the nearest inshore occurrences of living coral at Site 2.

The basalt boulders of the fishpond wall harbor a diverse fauna of sea urchins (*Echinometra mathaei*, *Echinometra mathaei oblonga*, *Tripneutes gratilla*, and *Echinothrix diadema*). A dense growth of macrothallic algae occurs on some boulders just exposed at low tide. Fish are abundant among these rocks, although only the manini (*Acanthurus triostegus sandvicensis*) and maomao (*Abudefduf abdominalis*) could be recognized in the turbid water. The bottom of the fishpond is covered with a silty-sand. This sand deposit is pocked with burrows of an unidentified, small crustacean (?Alpheidae).

The 50-meter transect line was laid out from the shoreline in four locations at Site 2 (Fig. 6). Transect B covered the fishpond from a point just north of the Waipuilani Gulch outlet to the outer seawall. The two quadrats selected randomly for algal abundance determinations were both devoid of macroalgae, a characteristic of the bottom over the entire 5-meter line. Transect A was established directly seaward of the hyperhaline pond at this site. Randomly selected quadrats on this line were at 15 and 36 meters. A second transect in the A-series (transect A(N)) was run through a basalt boulder field at the beach some 40 meters north (toward Kalepolepo) of transect A. Algal quadrats on this line were sampled at meter marks 8 and 31. Transect A(S) was placed 30 meters south of transect A, about 10 meters from the outside of the northern wall of the fishpond. This line crossed predominantly sand bottom lacking macrothallic algae. Results of species determinations and algal abundance (expressed as dry weight per m^2) in the quadrats are given in Table 6.

With the exception of sample A(N)-8, the results on algal abundance are typical for areas of limestone rubble and boulders on this reef. Foliose forms are rare or severely cropped. Filamentous and turfy algae (e.g., *Polysiphonia*, *Ceramium*) are present, but cover only a small proportion of the available hard bottom. Fine sand and silt collects around small patches of these algae. The dense growth of foliose algae in quadrat 8 of transect A(N) characterizes the upper sublittoral on the cluster of basalt boulders at the north end of the beach.

Site 3 (Kalama Park): A portion of the drainage culvert at Kalama Park is occupied by a pond containing water at slightly less than 1 $^{o}/oo$ salinity (on August 21). Two mangrove trees (*Rhizophora mangle*), each between 3 and 4 meters high, border the pond. Numerous small poeciliid fish (*?Gambusia*) and tadpoles (*Bufo marinus*) live in the water. Introduced grasses and sedges are growing in and around the pond, and several ironwood trees (*Casuarina equisetifolia*), with up to six-inch diameter trunks, have become established in sand deposited behind the seaward outlet of the culvert.

Table 6: Dry weight of algal species in meter-square quadrats at Site 2.

<u>Transect A(N), quadrat 8:</u>

*Ulva fasciata***	140.36 gms.	
Gracilaria coronopifolia	54.96	
Grateloupia hawaiiensis	30.13	
Grateloupia filicinis	5.48	
Total:		230.9 gms./m^2

<u>Transect A(N), quadrat 31:</u>

Ulva fasciata	0.82	
Polysiphonia hawaiiensis	0.37	
Pterocladia capillacea	0.10	
miscellaneous	0.02	
Total:		1.3 gms./m^2

<u>Transect A, quadrat 15:</u>

Polysiphonia hawaiiensis	0.76	
miscellaneous (*Ulva fasciata*, others)	0.01	
Total:		0.8 gms./m^2

<u>Transect A, quadrat 36:</u>

Polysiphonia hawaiiensis	2.34	
Ceramium sp.	0.18	
miscellaneous (*Ulva fasciata*, others)	0.03	
Total:		2.6 gms./m^2

** Large ribbon-like fronds, deep green in color, apparently a good deal healthier than most of the *Ulva fasciata* collected in other quadrats.

The reef flat off Kalama Park is similar in most respects to the reef flat at Site 2. Some small heads, and an occasional massive head (over one meter across), of *Porites lobata*, occur between 100 and 150 meters seaward of the basalt revetment along the shore. Also seen are a few heads of *Pocillopora meandrina* and *Porites compressa*. None of these occurrences of live corals constitute a flourishing reef assemblage. Dead heads of coral colonies are common. Large brittle stars (*Ophiocoma* sp.) and the urchin, *Echinothrix diadema*, are present. Within 50 meters of shore, a head of *Porites evermanni* was noted, as were scattered heads of *Pocillopora damicornis* and *P. meandrina*. Most of the *Pocillopora* here was either dead, or had only a small portion of the head covered with living tissue. A few fishes were encountered on the reef flat, including juvenile maomao (*A. abdominalis*), juvenile and adult manini (*A. t. sandvicensis*), *Chaetodon miliaris*, *Dascyllus albisella*, and juveniles of the wrasse, *Thalasomma duperreyi*. Only *T. duperreyi* were particularly abundant.

Inside 50 meters of shore, macrothallic algae becomes a prominant feature on the bottom. The outer portions of this "algal belt" is dominated by *Sargassum echinocarpum*. Closer to shore, algal diversity is high (see Table 7), and includes several species popular as food items (e.g., *Gracillaria coronopifolia*, or "ogo"). The flourishing algal assemblage terminates near shore in conjunction with the change in substratum from rubble (offshore) to sand (sublittoral extension of the beach). Scattered patches of sand on the reef flat frequently harbor an abundance of the tubes of a polychaete worm (Chaetopteridae).

One 50-meter long transect was laid perpendicular to shore directly in front of the drainage culture (transect C; see Fig. 7). Two other lines, one 50 meters north of the culvert (transect C(N)) and one 40 meters south (transect C(S)) of the culvert were likewise established perpendicular to the

Table 7: Dry weight of algal species in meter-square quadrats at Site 3.

Transect C(N), quadrat 43:

Sargassum echinocarpum	121.60 gms.	
Gracilaria coronopifolia	7.88	
Laurencia nidifica	5.86	
Ulva reticulata	1.39	
Dictyopteris plagiogramma	0.97	
Hypnea cervicornis	0.66	
Dictyota acuteloba	0.04	
miscellaneous (*Ulva fasciata*, others)	0.10	
Total:		138.5 gms./m^2

Transect C, quadrat 17:

Ulva reticulata	3.55	
Hypnea cervicornis	1.17	
Ulva fasciata	1.13	
Acanthophora spicifera	0.90	
Laurencia nidifica	0.39	
Jania capillacea	0.35	
Sargassum echinocarpum	0.25	
Dictyota acuteloba	0.11	
Jania sp., *Corallina* sp., *Amphiroa* sp.	0.87	
Polysiphonia hawaiiensis (some *Ceramium*)	0.19	
miscellaneous (*Enteromorpha* sp., *Lyngbya* sp., *Dictyota crenulata*, *Hypnea* sp.)	0.67	
Total:		9.6 gms./m^2

Transect C, quadrat 40:

Grateloupia filicina	0.25	
Laurencia nidifica	0.16	
Enteromorpha sp.	0.14	
Hypnea cervicornis	0.11	
Ulva reticulata	0.07	
Polysiphonia hawaiiensis	0.07	
Ulva fasciata	0.02	
miscellaneous (*Dictyota crenulata*, *Lyngbya* sp., others)	0.05	
Total:		0.8 gms./m^2

Transect C(S), quadrat 47:

Laurencia nidifica	13.56	
Padina crassa	12.68	
Ulva reticulata	11.90	
Ulva fasciata	7.15	
Dictyota acuteloba	2.27	
Polysiphonia hawaiiensis	2.03	
Gracilaria coronopifolia	1.27	
Acanthophora spicifera	1.25	

Table 7 (Continues)

Jania capillacea	1.00	
Dictyota crenulata	0.82	
Hypnea cervicornis	0.70	
Grateloupia filicina	0.64	
Laurencia succisa	0.55	
miscellaneous	0.41	
Total:		56.2 gms./m^2

basalt revetment. Randomly selected quadrats for the collection of algae were placed at meter-marks 22 and 43 on transect C(N), at marks 17 and 40 on transect C, and at marks 13 and 47 on transect C(S). Quadrat 22 on transect C(N) corresponded to the area of silt bottom (see page 22), and quadrat 13 on transect C(S) covered only sand bottom. Neither of these two quadrats contained macrothallic algae. The results obtained from the other quadrats (Table 7) show nearly comparable species lists in each area sampled, although dry-weight of algae per meter-square varied between 0.8 and 138.5 gms.

Several polychaetes were found to be abundant in the silt deposit in the vicinity of transect C(N). These species are listed in Appendix E, followed by the site designation, 3 si. A box crab (*Calappa* sp.) was observed on sand along transect C.

Site 4 (Keawakapu Beach Park): The extensive sand deposit sloping off into deep water from the beach at Keawakapu is without larger epifaunal species. Several *Tripneustes gratilla* and one *Actinopyga mauritiana* seen on the sand bottom are presumed to have been washed there from nearby hard bottom areas. Several large ulua (*Carangoides* sp.), a large milkfish (*Chanos chanos*), and cornet fish (*Fistularia petimba*) were seen in the water column above the sand bottom.

Directly off the low rocky headland at the south end of the beach and immediately south of the outlet from Inoaole Gulch, is a basalt spur extending to a depth of at least 12 meters. This spur harbors a moderately diverse coral assemblage and an abundance of several species of sea urchins. Outer rocks of the headland, splashed by waves, are covered in a narrow band with the alga, *Ahnfeltia coccinna*. Macrothallic algae is absent, however, from basalt or limestone surfaces below the littoral zone. A diverse fish fauna (see Appendix E) is associated with the basalt spur and its veneer or coral growth.

Two transects across the spur were surveyed (see Fig. 8). The deeper transect (transect 1) was placed about 30 meters seaward of the emergent rocks at the point. Depth over the spur is between 1 and 2 meters here, whereas the depth to adjacent sand bottom is 3.5 meters. A shallower transect (transect 2) was located 20 meters toward shore from, but parallel to, transect 1. Depth here is about 1 to 1.5 meters, with some rocks nearby extending up to sea level, and sand bottom adjacent at a depth of 2.5 meters.

Along transect 1, the percent cover of corals and bottom type, and the number of each species of sea urchin encountered, were determined in 19 contiguous meter-square quadrats. On transect 2 this information was obtained from 8 randomly selected quadrats on the 21 meter line. The point-intercept method was applied to 18 marks on transect 1 and 21 marks on transect 2. The species of sea urchins present and their average abundance along each transect is presented in Table 8. Results of both the quadrat and point-intercept methods of estimating coral cover and bottom type are presented in Table 9.

On transect 1 the most abundant sea urchin was *Echinothrix diadema*, whereas *Echinometra mathaei* predominated in shallower water (transect 2). *Tripneustes gratilla* had a low average density in both transects, although this urchin was seen to become the dominant species where the spur continued into deeper water ($>$ 7 meters). The dominant coral on both transects was *Porites lobata*, with *Pocillopora damicornis* second in abundance (i.e., cover). In deeper water, *Porites compressa*, only present in the transected area, was observed to be clearly the dominant coral species. Total coral coverage was slightly greater on the deeper transect (transect 1) than the shallow transect (transect 2). Total cover appeared to increase into deeper water, although the extent of hard bottom decreased.

Table 8: Echinoderms (species present and their abundance) in transect across the rocky spur at the south end of Keawakapu Beach. Values given are average number per m^2.

Species	Transect 1	Transect 2
Echinometra mathaei	0.74	10.12
Echinothrix diadema	7.63	8.62
Heterocentrotus mammillatus	3.21	2.62
Tripneustes gratilla	1.16	0.75
Echinometra mathaei oblonga	-	0.12
Echinothrix calamaris	0.05	-

Table 9: Summary of meter-square quadrat and point-intercept estimates of coral abundance and bottom type in two transects across the basalt spur at Keawakapu Beach Park (Site 4). Values are percent cover.

	Transect 1		Transect 2		Average of Quadrats
	Quadrat	Intercept	Quadrat	Intercept	
Madreporarian corals:					
Porites lobata	20.0	16.7	16.2	19.0	18.9
Pocillopora meandrina	7.9	22.2	8.0	3.7	8.0
Montipora patula	1.4	-	-	-	0.9
Leptastrea purpurea	0.8	-	1.1	-	0.9
Montipora verrucosa	0.6	-	0.1	-	0.4
Montipora flabellata	0.2	-	0.6	-	0.3
Montipora verrilli	0.2	-	-	-	0.1
Porites compressa	0.2	-	0.1	-	0.1
Porites evermanni	< 0.1	-	-	-	< 0.1
Total	31.3	38.9	26.1	21.7	29.7
Zoanthid (soft) corals:					
Palythoa tuberculosa	0.6	-	0.9	-	0.7
Bottom type (other than live corals):					
Basalt (may have a thin veneer of limestone)	59.7	16.7	72.2	28.6	63.5
Dead *Poc. meandrina*[1]	-	33.3	-	47.6	-
Sand (in pockets)[2]	8.4	11.0	0.8	0.0	6.1

[1]Not a category in the quadrat estimates and therefore included in the basalt/limestone veneer values.

[2]Sand occurs in pockets on the basalt spur. However, the value of 8.4 % for quadrat method estimates on transect 1 includes one quadrat overhanging the edge of the spur and containing 70 % sand bottom of the adjacent (deeper) sand deposit. This circumstance also accounts for 5 % of the 11 % sand in the line-intercept method applied to transect 1.

DISCUSSION

NUTRIENTS

Nutrient concentrations were high at all four locations, although Sites 1 and 2 had far higher concentrations of nitrate than Sites 3 and 4 (Table 2). Concentrations of ammonia nitrogen and orthophosphate were similar at all the study sites. Total inorganic phosphorus values ranged from 0.11 to .27 μg-at P/l. These phosphorus values are non-limiting to phytoplankton growth. The total inorganic nitrogen concentrations ranged from 0.76 to 5.87 μg-at N/l, values substantially above concentrations necessary for phytoplankton growth. Inorganic nitrogen concentrations in excess of 0.4 to 0.5 μg-at N/l are non-limiting. The Kihei values are also high relative to concentrations found in other Hawaiian marine environments. For example, Krasnick (1973) reports mean values for total inorganic nitrogen of 3.36, 0.32, and 0.53 μg-at N/l for the south, transition, and north sectors of Kaneohe Bay, respectively. Total inorganic nitrogen at an open coastal station at Barbers Point average less than 0.30 μg-at N/l (ECI, 1975). Inorganic nitrogen values averaged 0.37 μg-at N/l in open coastal waters south of Lahaina (ECI, 1976). Nitrate nitrogen values measured off west Maui's northern coast between Makaluapuna and Alaeloa Points averaged 0.74 μg-at NO_3-N/l (ECI, 1971).

Although the nutrient sampling program in this study was necessarily limited, it is interesting to compare our data with those from a previous study in Maalaea Bay (Cattell and Miller, 1972). Station 4 in the 1972 study coincides closely with our Site 1 and a comparison of these stations shows remarkable similarity in concentrations of nutrients (see Table 10). Mean values listed in the table suggest that ammonia and phosphate show little variation anywhere in Maalaea Bay whereas mean nitrate concentrations rise in proximity to Kihei. The mean nitrate concentration for the Bay, reported by Cattell and Miller, is lower than the mean obtained in this survey,

Table 10: Comparison of nutrient concentrations determined during the present study with previous values from Maalaea Bay (Cattell and Miller, 1972).

	Present Study		Cattell & Miller Survey	
	$\bar{x}$ of Sites 1 through 4	Site 1 only	Station 4	$\bar{x}$ of 4 Stations
phosphate	0.17	0.15	0.15	0.14
ammonia	0.42	0.46	0.35	0.38
nitrate	2.25	2.65	2.25	0.75

a difference that is related to the wider distribution of sampling points in 1972. Further, the data reported by Cattell and Miller include six samplings over a seven week period in January and February. Nonetheless, considerable similarity exists between the nutrient data reported by Cattell and Miller with those obtained for this study, which suggests that the nutrient concentrations given in Table 2 are representative of the nearshore environment at Kihei.

The high nitrate concentrations measured at Stations 1 and 2 are probably the result of ground water seepage into the nearshore marine environment. Salinity depression (page 10) at Site 2 (the area of the highest nitrate concentrations) supports this suggestion. Site 1 undoubtedly also receives groundwater inputs, but this input is not reflected by a marked salinity depression because of the greater depth of water nearshore at Site 1 as compared with Site 2 (see pages 10 and 16). Because phosphorus concentrations are relatively stable throughout the bay the N:P ratios presented in Table 2 appear to correlate with high rates of ground water inputs. Sites 1 and 2 have N:P ratios of about 20 whereas the N:P ratios at Sites 3 and 4 are less than 10. Similar ground water contribution of nitrates have been demonstrated at Waialua Bay (ECI, 1971), Barbers Point (ECI, 1975), Honokahau Harbor (Oceanic Institute, 1975), and at Lahaina (ECI, 1976). The nutrient regime in water of Maalaea Bay can be characterized as relatively stable with respect to ammonia and phosphorus values coupled with highly variable nitrate values that presumably correlate with ground water seepage into the marine environment.

TURBIDITY

Turbidity values measured during the survey ranged from 0.28 to 2.06 FTU. The highest turbidity values were found at Sites 2 and 3, although all of the turbidities are high when compared to other, similar open coastal waters in

Hawaii. Turbid, discolored water is a general characteristic of nearshore coastal water in this area. Suspended material creating this turbidity appears to be of terrestrial origin deposited into nearshore marine waters by seasonal stream runoff and aeolian transport (see page 44). Shallowness of the offshore shelf at Sites 2 and 3 allows wind driven waves to maintain suspension of particles in the water column. The maximum depth of water at each sampling site is 10 to 12 meters at Sites 1 and 4 and less than 3 meters at Sites 2 and 3.

The nephelometric turbidity measurement assesses the light scattering properties of suspended particles. Bottom sediments collected nearshore contain a relatively high proportion of basalt or other non-limestone material, and the particles in suspension may be predominantly terrigenous in origin (see page 41). It can be expected that white calcium carbonate reflects more light and thus generates higher nephelometric turbidity values per unit concentration of suspended material than would darker, light-absorbing basaltic particles.[1] Thus, the turbidity values reported herein overestimate the light penetration of these nearshore waters. In other words, the concentration of suspended solids is probably much larger than the turbidity values indicate. Visibility is extremely poor. At Sites 2 and 3 the compensation depth (1% of surface light intensity) would likely fall between 1 and 2 meters, or approximately the depth of the reef surveyed at these sites.

Weather conditions were similar each day between August 19 and August 21. The wind was light (generally less than 5 mph) during the morning hours. Between 1100 and 1300 hours, wind speed increased (up to 25 mph), remaining strong through the evening. Water samples for turbidity analyses were taken during morning and afternoon periods in order to determine if turbidity values

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[1]See Ekern (1976) for a discussion of relative light scattering properties for several minerals found in Hawaiian waters.

varied in response to diurnal changes in wind speed. Sites 1 and 4 showed no significant change between morning and afternoon. Site 2 showed a decrease under high wind conditions which likely is a sampling anomaly. Only Station 3 showed a significant increase in turbidity values during the afternoon sampling. Generally, the time of sampling has little or no effect on turbidity values. For the reasons discussed above, either suspended solids determinations or light extinction measurements would be more sensitive tests of wave induced suspension of particulates.

Water samples for turbidity measurements were taken approximately 50 and 100 meters offshore at each site to ascertain if there was significant spatial variation in values. The turbidity values at Sites 1, 2, and 4 do not appear to vary with distance from shore. At Site 3, however, the mean turbidity at the 100 meter station was about half that measured at the 50 meter station (i.e., 1.22 versus 2.15 FTU). This decrease in turbidity is likely a function of distance from a prominent silt deposit north of the outlet of the Kalama Park drainage culvert (see page 22) rather than distance from shore. Turbidity, then, shows little or no correlation with distances up to 100 meters from shore at the study sites.

SEDIMENTS

The results of the sediment analyses produced some interesting patterns. For the most part, the samples are remarkably similar with respect to grain-size distribution (see Appendix C and Figs. 4 and 5). Moment statistics (Table 3) reveal medium to fine grain sands with low variation in the distribution of grains among the size fractions. Despite the general similarity of sediments along this coast, most of the samples fall into one of two main groups: a south-Kihei group (represented by samples 1 through 9) and a north-Kihei group (represented by samples 11 through 13 and 15 through 20). Samples

10 and 14 represent sediments from 50 meters offshore on the shallow reef flat and comprise a third group characterized generally by high calcium carbonate content (>80%), poor sorting, and low, mean *phi* as compared with the other samples.

North-Kihei sediments tend to be finer grained than south-Kihei sediments. The mean grain size of the south-Kihei sediments (mean of samples 1 through 9 combined) is 2.4 ϕ; that of the north-Kihei sediments (samples 11 through 20, excluding 14) is 2.9 ϕ. Sediments from submarine deposits in the northern area have a smaller mean grain size than dry beach sands. By comparing the distribution of grains in a sample collected from the dry beach deposit with a sample collected from the connected submarine deposit (see Fig. 9), it is seen that the difference in mean grain size can be accounted for by removal of the fines (very fine sand and silt fractions). Undoubtedly, this process (deflation) is accomplished by the onshore winds selectively removing the lighter particles which are blown inland. Mean grain size of north-Kihei sediments, excluding beach samples, is 3.0 ϕ, whereas that of the beach samples is 2.2 ϕ. However, mean grain size of south-Kihei sediments combined, but excluding beach samples is 2.4 ϕ, the same value obtained for south-Kihei beach sands. Reference to Fig. 9 suggests deflation is occurring at Sites 3 and 4, although the low proportion of very fine sand and silt in sediments offshore produces a situation in which deflation does not greatly alter the mean grain size.

The calcium carbonate content of the samples shows a distinct division between north and south-Kihei sediments (Fig. 10). The north-Kihei sediments (excluding beach sands) contain generally between 55 and 61% calcium carbonate by weight, although sample 20 taken on the nearshore shelf at Kaleia contained 71% calcium carbonate by weight. The south-Kihei sediments are all composed of 80% or more calcium carbonate by weight. Comparison of calcium carbonate

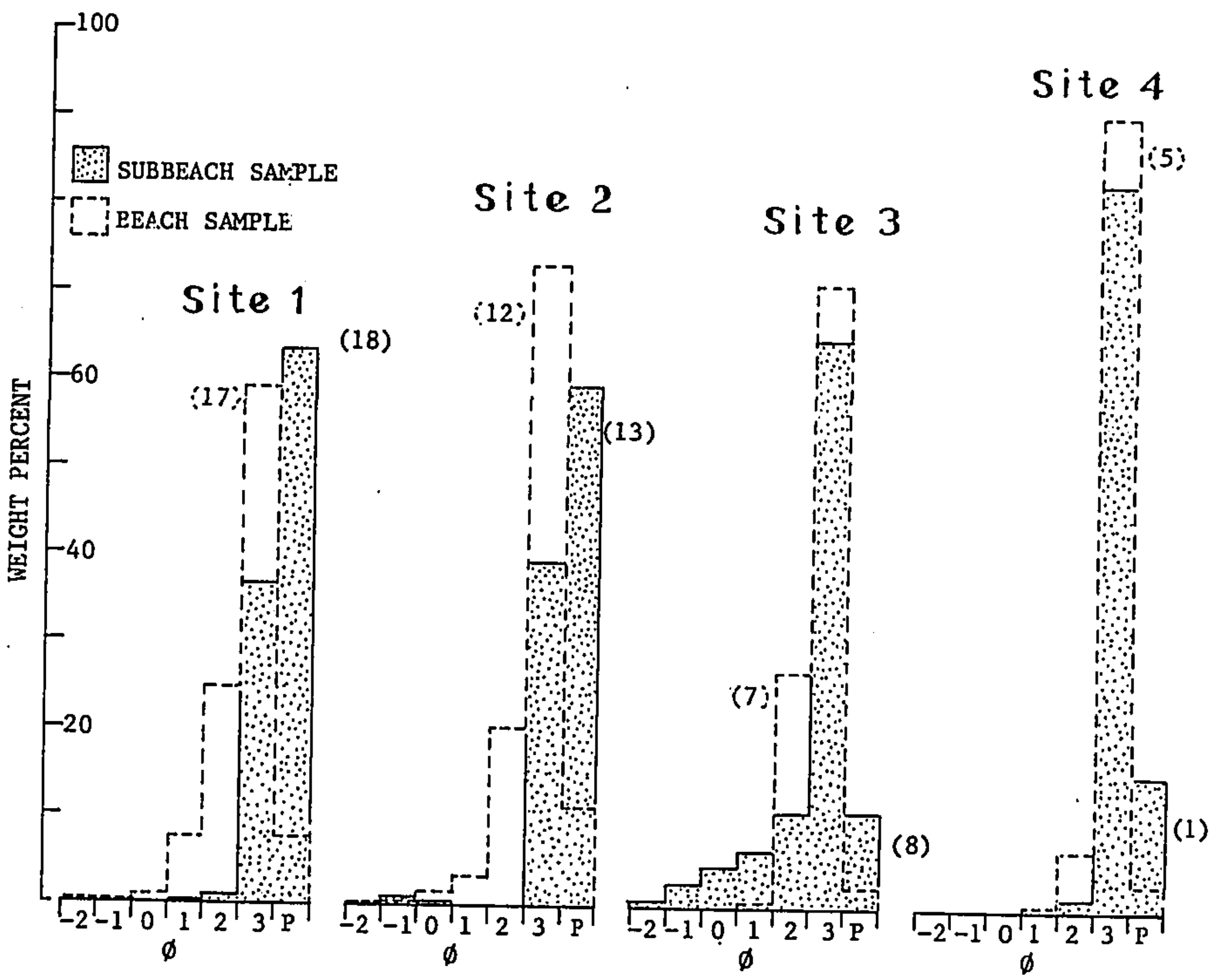

Figure 9: Comparison of grain-size distribution of beach sands with samples from the subbeach (i.e., submarine deposit continuous below sea level with the beach deposit) at each of the primary sites. Sample numbers are given in parentheses.

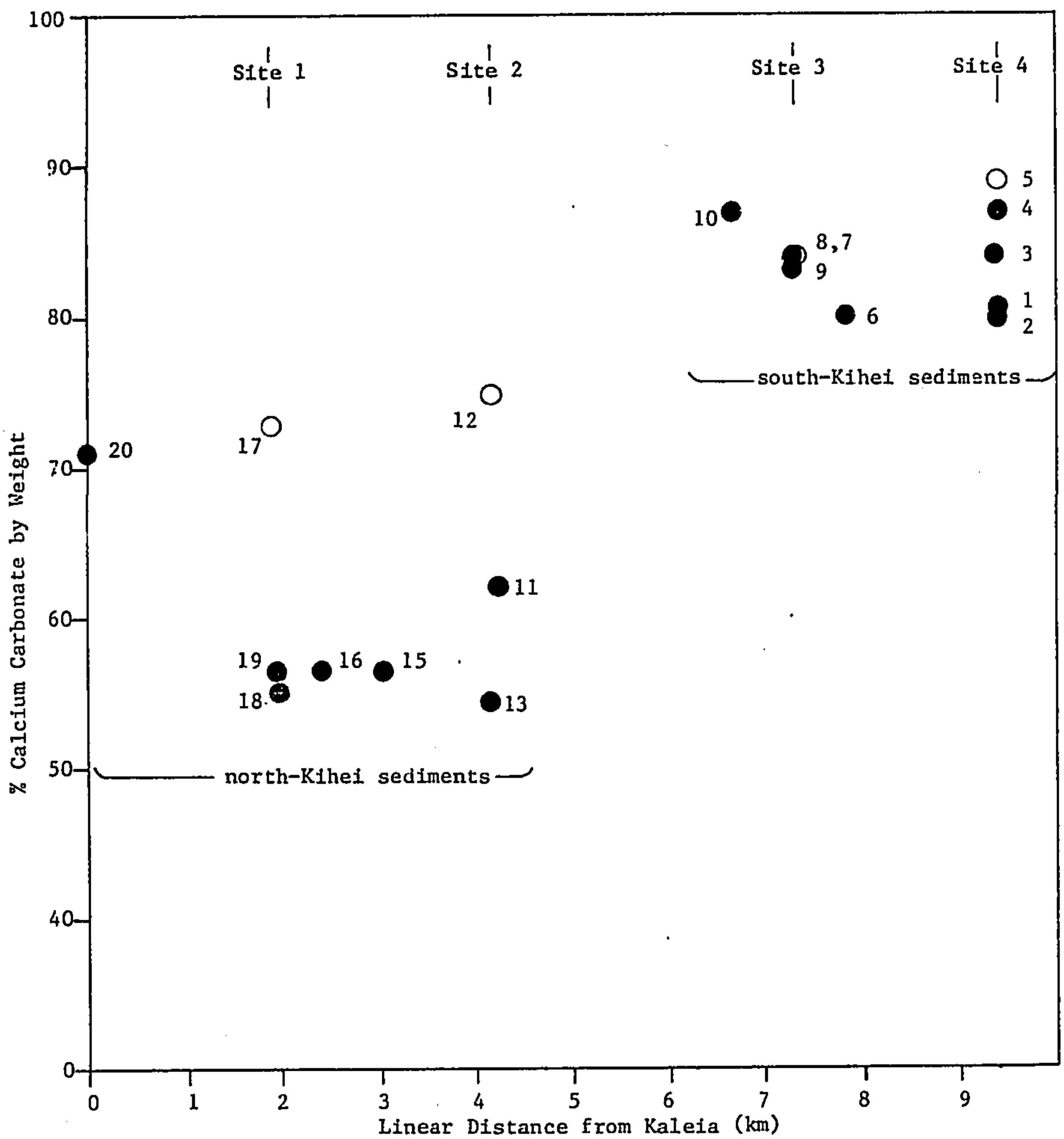

Figure 10: Percent calcium carbonate in sediment samples from the Kihei area plotted as a function of straight-line distance from Kaleia at the north-end of Maalaea Bay. Open circles are dry-beach sediments.

content of dry beach deposits with their corresponding submarine sediments reveals a sharp increase in $CaCO_3$ on the beach in the north-Kihei samples. This difference suggests that the non-carbonate portion (i.e., presumed terrigenous sediments) is concentrated in the very fine sand and silt fractions. The proportion of calcium carbonate on the beach is increased relative to submarine sediments by selective removal of the terrigenous matter.

This difference is less apparent in the south-Kihei samples, in part because deflation is less well-marked at Sites 3 and 4. In addition, fine sediments in these areas may contain a lower proportion of terrigenous material than at Sites 1 and 2. A sediment sample, as such, was not collected from the silt deposit along transect C(N) at Site 3 (see page 22). However, a sample of this deposit was obtained for biological purposes. An aliquot was dried and tested for $CaCO_3$ content, giving a value of 70.5%.

These results suggest a sediment cycle involving the addition of fine terrigenous material to the marine environment, either as wind-blown particles from the Kealia Floodplain (upwind of the survey area), or as runoff from the Kealia and Kihei Floodplains. A portion of this detrital material, in suspension, is concentrated along the Kihei coast north of Kalama Park by wind driven currents, eventually moves onshore (i.e., is deposited on the beaches), and is blown inland. Some of this material is redeposited into the marine environment during infrequent floods.

Beaches at Kihei, Kalama Park, and Keawakapu were studied by Moberly and Chamberlain (1964) during several visits in 1962 and 1963. Samples of sediments from the beaches and offshore deposits were collected and analyzed for size-fraction analysis, calcium carbonate content, and grain composition. The method used by Moberly and Chamberlain to determine calcium carbonate versus detrital (i.e., terrigenous) content differed from that used in the present survey (see page 6). Samples were treated with cold HCl and the insoluble residue washed, dried, and weighed. This component proved upon examination to be predominantly volcanic in origin. Any organics soluble in HCl would not be included in the detrital fraction, whereas in the gasometric determination of calcium carbonate, HCl-soluble organics would be included in the detrital fraction. It is not known to what extent this difference in methodology will influence comparison of results. The HCl-soluble organic fraction is believed to be small relative to other fractions in the sediments compared below.

At Keawakapu, offshore sediment samples collected by Moberly and Chamberlain had grain size distribution and sorting characteristics very similar to our Site 4 samples. The insoluble residue (detrital) fraction ranged from a low of 4% in an April 1962 sample to a high of 11% in an August 1963 sample. A comparable offshore sample in August 1977 (e.g., our sample 2) had a residual (non-calcium carbonate) fraction amounting to 21% of the dry weight.

Samples collected from offshore of Kalama Park for the Hawaii Beach Systems study were similar in grain size and sorting to our samples 6 and 8 from the same general area. The detrital fraction ranged from 9% in a September 1962 sample to 12% in a February 1963 sample. Our determinations yielded detrital compositions of 21% for sample 6 and 16% for sample 8.

All but one of the five offshore samples collected by Moberly and Chamberlain at Kihei Beach closely resembled our sample 16 (collected in the same general area). Results of detrital analysis from the earlier study produced a low of 16% in September 1962, and a high of 36% in August 1963; sample 16 from the present study had a detrital content of 39%.

At all of the sites compared, the proportion of non-calcium carbonate grains appears to have increased since 1962/63. However, without further analysis it cannot be stated that the proportion of very fine sedimentary material (i.e., silt and clay) in the offshore environment has also increased.

ECOLOGY

Considering biological and physiographical aspects, a distinct division occurs between Sites 3 and 4. Site 4 (Keawakapu Beach Park) is representative of the coastal zone to the south where coral bottom is well-developed off basalt headlands, and poorly developed or absent off intervening stretches of sand beach (see Environmental Consultants, Inc., 1974). Coral reefs, as such, are absent, although the coral assemblages in Ahihi Bay (near the southwest tip of east Maui) and off the north side of Puu Olai (2 km. south of Makena) are spectacular for their diversity and cover. Comparisons can be made with the results of the ECI study (Makena to Ahihi) and a study by Bowers (1973) which involved the coastline between Keawakapu and Polo Beach (Wailea). Table 11 presents data on coral cover from Station 1S in the ECI report (the rocky point at the south end of Poolenalena Beach, 4 km. south of our Site 4), Bowers' Station 1 (Keawakapu), and Bowers' data combined (4 stations between Keawakapu and Polo beaches), and our Site 4, transects 1 and 2 combined. Note from information given in the table that two methods of sampling bottom cover are represented in the data.

Despite the different methods used and the possibility of different depths having been sampled, the dominant corals (*Porites lobata* and *Pocillopora meandrina*) show fairly consistant cover values. Each of the other species listed accounts for less than 6% of the bottom in each survey (for most species this value is considerably less than 6%) and variation in percent cover, as well as presence or absence along a transect, can be expected.

Comparison of data on echinoderm densities in these three surveys is also possible. However, the marked zonation of species indicated by our present data suggests that different placements of the transect lines with respect to depth would contribute significantly to variation in comparisons between surveys. In general, *Echinometra mathaei*, was not abundant at any of the

Table 11: Comparison of data on coral and substratum cover from three marine reconnaissance surveys conducted between Keawakapu and Makena (Maui) in 1973, 1974, and 1977. Values are percent cover.

	BOWERS (1973) KEAWAKAPU (1)*	BOWERS (1973) ALL SITES (1)*	ECI (1974) STA 1S (1)*	ECI (1974) STA 1S (2)*	ECI (1977) SITE 4 (2)*
Live corals:					
Pocillopora meandrina	10.0	16.6	8	12	8.0
Pocillopora eydouxi	-	-	-	< 1	-
Porites lobata	17.2	16.6	12	17	18.9
Porites compressa	0.8	2.5	-	-	0.1
Porites brighami	-	-	-	< 1	-
Porites evermanni	-	-	-	-	< 0.1
Montipora patula	-	-	6	2	0.9
Montipora verrucosa	3.1	3.7	2	< 1	0.4
Montipora flabellata	-	-	-	1	0.3
Montipora verrilli	-	-	-	-	0.1
Leptastrea purpurea	-	-	4	1	0.9
Leptastrea bottae	5.5	2.2	-	-	-
Pavona varians	-	-	-	2	-
Cyphastrea ocellina	3.9	3.9	-	< 1	-
Fungia (Pleuractis) scutaria	-	0.2	-	-	-
*Palythoa tuberculosa***	-	-	2	< 1	0.7
Total:	40.5	45.7	34	40	30.4
Substratum (other than live corals):					
Hard bottom	28.9	37.9	66	59	63.5
Sand bottom	30.0	16.3	0	1	6.1

*Methods: (1) Point-intercept method; Bowers, 128 points per site; ECI, 50 points per transect (station). (2) Quadrat method; ECI (1974), 10 one meter square quadrats; ECI (1977), 27 one meter-square quadrats.
**soft zoanthid coral

Makena-Ahihi stations (ECI, 1974). *Echinothrix diadema* and *Tripneustes gratilla* (having densities of 4.2 and 1.5 individuals/m^2 respectively at Station 1S) were the most abundant species encountered. Only *E. mathaei* (with an average density of 0.13 individuals/m^2) and *T. gratilla* (with an average abundance of 1 individual/m^2) were recorded by Bowers (1973) at Keawakapu. These values may be compared with our results in Table 8. The absence of *Heterocentrotus mammillatus* at Bowers' Station 1 (Keawakapu) and the density of 3.2 individuals per m^2 on our transect suggests either an expression of temporal variability or that different areas were sampled. Maximum average density of *H. mammillatus* (1.47 ind./m^2) reported by Bowers was at his Station 4 (Polo Beach). Visual estimates presented in the ECI (1974) report for shallow waters off Ahihi Bay are 8 *H. mammillatus* per m^2. However, quadrat counts on transect 1S give an average density of only 0.4 individuals per m^2 for the slate-pencil urchin.

These comparisons are intended primarily to demonstrate the general similarity of the nearshore marine biota at Site 4 with that on the open coast south of Keawakapu. The brief survey of fishes conducted at Site 4 does not fairly represent their diversity in the general area. For example, Bowers (1973) recorded 316 individuals representing 43 species at Keawakapu (he does not provide a listing of the species). The species lists contained in the Makena-Ahihi report (ECI, 1974) and surveys conducted by the State of Hawaii, Division of Fish and Game (1970, 1972) in the Ahihi Bay-Cape Kinau-La Perouse Bay regions should be consulted as representative of coastal waters from Keawakapu south.

Somewhere north of Keawakapu, the nature of the nearshore environment changes. Although not determined in this survey, this change likely corresponds with the occurrence of the offshore reef[2] seen at Sites 2 and 3. Inspection of

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[2]Although here termed a "reef", by which is implied a biogenic fringing reef, the topography directly offshore may be a submarine shelf formed as part of the Kihei Floodplain, and now covered with a thin deposit of biogenic sediments. The shelf slopes gently to seaward, generally reaching a depth of between 1 and 2 meters at 200 meters offshore. The outer edge of this "reef" was not inspected, but from the shore, appears not to shallow along its outer margin as would be expected of a true fringing reef.

U.S. Geological Survey maps (see particularly Puu o kali quadrangle of the 7.5 minute topographic series) suggests the south end of Kalama Park (Kaluaihakoko) as the region of transition. The Kihei Floodplain (as a topographic feature of Holocene aluvium) terminates at this point. However, Moberly and Chamberlain (1964) mention a reef at the north end of Keawakapu Beach, 2.5 km. farther south along the coast. Depth contours on the Puu o kali quadrangle topographic map indicate that if the reef is continuous between Kalama Park and Keawakapu, its width must be less than half the 400 meters reported by Moberly and Chamberlain for reef width off Kalama Park.

The nearshore environment along the segment of coast having an offshore reef or shelf (represented by our Sites 2 and 3) is one of generally poor water quality. Successful recruitment of coral planulae is low, and the survival of established colonies tenuous. The nearshore reef flat appears to lack diversity of benthic biota and reef fishes. Biotic diversity is related to relief. The basalt boulders of the fish pond wall at Site 2 harbored more individuals and kinds of sea urchins and fishes per unit area than low relief, rubble and small boulder areas adjacent or farther offshore. Coral colonies seen on the reef flat tended to be located on larger boulders. Admittedly, a more flourishing reef biota may be present farther offshore than the limits of reconnaissance undertaken by this survey.

The generally degraded condition of the back reef flat appears directly related to sediment loads. Onshore winds and wind waves concentrate suspended and settled sediments in the nearshore environments (see page 44), and to some extent this process limits the kinds of organisms able to establish populations there. The source of the fine particles is not firmly established. Sediment analyses suggests input from the terrestrial environment, and observations reported by Buske (B-K Dynamics, Inc., 1972) and Maciolek (1971) on great quantities of dust blown off the Kealia Floodplain is one likely source. Stream runoff is another possible source of sedimentary material, although this input would be concentrated during winter storms. Sediments carried into nearshore marine areas by land drainage is apparently spread out and redistributed in a matter of months. No local accumulations of stream deposited, terrigenous material were observed at any of the sites. The silt deposit at Site 3 (page 22) is predominantly calcium carbonate.[3]

The physical division between north-Kihei and south-Kihei sediments poses some interesting questions. This division appears not to coincide with changes in either water quality (i.e., turbidity), nearshore physiography, or biotic assemblage. With regard to the latter, a more detailed investigation of the benthic fauna might reveal greater differences between Sites 2 and 3 than demonstrated by data presented here. Certainly the different algal assemblages at these sites hint at such. Further, the poor visibility at both sites tends to bias observations by creating a sense of sameness and limiting opportunities for the discovery of unique elements. High turbidity also gives an impression of environmental degradation which may not be fully warranted. For example, the algal samples collected at Site 3, upon inspection and washing in the laboratory, were found to harbor an abundance of small echinoderms (brittle stars and sea stars, see Appendix E) and amphipods.

The data presented here do not provide an answer to why terrigenous sediments are more prevalent at Site 3 than at Site 2. Two explanations can be suggested: (1) a greater total volume of sediments are transported into the offshore environment by intermittant stream flooding in the north than are supplied in the south; or, (2) currents concentrate terrigenous sediments from

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[3]Also, sediments accumulated in the fishpond at the mouth of Waipuilani Gulch (sample 11) have a slightly higher calcium carbonate content than nearby reef flat sediments (Site 3).

upper Maalaea Bay along the shoreline between Kihei (Site 1) and Site 3.

North of Site 2 bottom topography again changes. The offshore shelf gradually narrows and disappears (or deepens). The bottom at Site 1 is sand without limestone rubble, boulders, or reef structure (rounded basalt boulders are present nears shore). A major survey of northern Maalaea Bay was undertaken by Kinzie in 1972. Nine transects quantifying bottom type, benthic fauna and flora, and fishes were undertaken between Kihei on the east and McGregor Foint on the west side of the Bay. The Kihei transect (Kinzie's no. 9) was laid from the Kihei Pier, and extended westward to a depth of 19 meters. Bottom type recorded along six segments of the line was, in every case, sand. The only organisms noted were the "swimming" anemone, *Boloceroides mcmurrichi*, polychaetes (Sabellidae), a few snails (*Terebra* sp., *Nassarius* sp.), the crab, *Macrophthalmus telescopicus*, and numerous burrows of alpheid shrimp with commensal gobies. Only *Terebra* sp. was found in water less than 10 meters deep. Kinzie's transect no. 8 was laid from the shore opposite the eastern half of Kealia Pond and extended offshore to the 17 meter contour. This line also crossed only sand bottom, harboring a similar fauna to that recorded on transect no. 9. Transect no. 7 in this series was placed offshore of the west end of Kealia Pond. Hard bottom was encountered along segments out to a depth of 2 meters, sand bottom thereafter. Benthic diversity recorded from the hard bottom was considerably greater than that found along transects 8 and 9. Some corals were present (at depths between 1 and 2 meters), although cover did not exceed 7% (mostly *Porites lobata* and *Pocillopora meandrina*) in any one square-meter quadrat, and averaged 2.3%. Other than the gobies commensal with burrowing alpheid shrimp, no fish were recorded from transects 8 or 9. Eighteen species were recorded from transect 7.

The Kinzie survey demonstrates that the nearshore environment characteristic of our Site 1 continues west to Kaleia. Beach rock and a narrow limestone shelf appear. Farther west (Palalau), a rich and, in many ways, unique, nearshore marine biota has been documented by Maciolek (1971). Transects described in Kinzie (1972) provide additional data from this area.

UTILIZATION

The survey area is one notable for its numerous beaches and beach parks. The County of Maui has amply provided for access and facilities along the shore, and these facilities are seldom utilized to capacity (e.g., parking was not a problem at any of the beach parks during the survey conducted over a three-day weekend). The more esthetic beaches occur at the south end of the survey area (Keawakapu, Wailea), and these beaches are the more heavily utilized for recreation. Seldom more than a half-dozen persons were seen on any of the beaches north of Kalama Park. Guests of the hotels and numerous condominiums in the area would seem to account for the majority of beachgoers at all sites. Beach utilization declines considerably when the wind speed increases during the afternoon.

Several parties of divers with spears were seen during the survey period at Sites 2, 3, and 4. The fishes observed inshore at Sites 2 and 3 would seem to provide little potential for sport. Shore-casting was observed infrequently at all of the sites. At Kalama Park, in the immediate vicinity of the culvert, a popular activity is the harvesting of edible seaweeds (*limu*). Table 7 includes seven species which appear on the list of most common Hawaiian algae in Abbott and Williamson (1974). Most persons engaged in harvesting at Kalama confined this to collecting algae washed up on the beach at the mouth of the culvert, although a few sought attached plants on the reef. Discussion with residents revealed that great quantities of algae wash up on the shore along this part of the coast when the surf is heavy (autumn and winter according to Buske, B-K Dynamics, Inc., 1972).

IMPACTS

The establishment of channel alignments, involving the construction of culverts, would not destroy unique or valuable aquatic resources along existing stream courses crossing the Kihei Flood plain. The lower reaches of these streams (gulches) are usually dry, and without indigenous biota (see Maciolek, 1971). The several ponds located behind the beach at sites investigated during the present survey, were inhabited by exotics (e.g., *Bufo marinus*, poeciliid fish). These ponds are unstable environments subject to wide salinity variation and destruction during floods.

This survey produced no evidence that the proposed channel alignments, drainage structures, and effluents from such structures under normal (low or no flow) conditions, will adversely affect the existing nearshore marine environment in the immediate vicinity of the four survey sites. The major concern, regarding potential impacts on marine areas, must consider the expected increase in sediments discharged from the Kihei watershed during flood conditions. The environmental impact statement for the Kihei Drainage Project (Sam Hirota, Inc., 1977) estimated an increase in sediment load after channelization of 29% for a 50-year storm, and sediment discharges for smaller storms might be increased 42 percent (in this case calculated on a runoff volume one-fifth that of a 50-year storm).[4] This increase amounts to 1350 tons of sediment in the first case, and 340 tons in the second case.

The impact of added sediment load is not easily ascertained. The ability of the nearshore and offshore environments to handle present loads is poorly known. Sediment transport into Maalaea Bay has probably increased since the development of agriculture in central Maui (County of Maui, 1970; Maciolek, 1971), contributing to the degradation of the marine environment along the

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[4]These values may pertain only to the approximately 2 miles (3 kilometers) of coastline between Kulanihakoi Stream and Kalama Park (encompassing our Sites 2 and 3); that is, the boundaries of the Kihei Drainage Project.

Kihei coast. The discharge of turbid water from Kealia Pond during winter flooding "is not severe enough to destroy or decimate the Maalaea coral reef community ... living at and to the west of the discharge point." (Maciolek, 1971, p. 11). In this part of Maalaea Bay, terrigenous sediments may not remain long in the vicinity of the reefs.

The differences in offshore topography noted herein suggest different sections of the Kihei coast handle sediments in different ways, or at least redistribute them at different rates. Greater depths of water immediately offshore of Sites 1 and 4, as compared with Sites 2 and 3, enhance settlement of silt and clay particles at the latter locations and therefore turbidity is far less of a problem. Further, at Sites 1 and 4, fine sediments are distributed over soft bottom and the impact on marine assemblages is expectedly less than at Sites 2 and 3.

Additional studies may be required to fully appraise the affects of anticipated increases in sediment loads to the marine environment. These studies should focus on physical processes in Maalaea Bay. In particular, a knowledge of water currents (under both normal and storm conditions) and the movement of silt and clay particles from their points of origin to areas of deposition warrants consideration. Water movement across the shallow reef flat (Sites 2 and 3) is likely wind-dominated. Thus, suspended solids tend to move onshore with littoral drift setting to the southeast (at least under the conditions obtaining during the present survey). Accumulation of silt would be concentrated in pockets formed by indentations along the coastline. On the other hand, the existing literature on the subject suggests offshore currents move to the north and west in upper Maalaea Bay. For example, Laevastu, Avery, and Cox (1964, p. 57) state:

> A northwestward current has been reported in Maalaea Bay (Coast and Geodetic Survey, 1963) but no reliable current observations seem to have been made anywhere along the southwest coast of Maui from Makena to Lahaina.

Buske (B-K Dynamics, Inc., 1972) measured a "moderate but consistent westward trend" along the coast of upper Maalaea Bay near Kealia Pond, and postulated a counter-clockwise circulation between Kihei and an offshore rip channel near Kanaio. However, Moberly and Chamberlain (1964) described the late summer current off Kihei Beach (our Site 1) as flowing to the southeast, i.e., in a direction opposite to that observed by Buske.

Assuming Buske's observations on currents in upper Maalaea Bay are accurate under most conditions, then coral reefs in the Palalau area could be subjected to turbidity arising along the north Kihei coast. The biological communities off Palalau have been described by Maciolek (1971) as comprising a unique marine resource. Maciolek emphasizes (p. 36) the need for studies "to determine current patterns in areal detail and under different meteorological conditions" as an adjunct to perpetuation of these marine ecosystems.

At the sites investigated, no unique marine resources would be adversely affected by proposed flood control improvements. Only at Site 4 is there an established coral community in close proximity to a stream outlet. Damage to this community could be mitigated by locating the drainage outfall toward the north end of Keawakapu Beach. However, the proposed flood control measures must be considered in the context of contributing to a general increase in terrigenous sediments in the nearshore environment. An obvious mitigation, which may not be practical at all locations, is the establishment of settling ponds in conjunction with channel construction. To be effective, such ponds might have to be dredged periodically. Reduction of sedimentary inputs from Kihei drainage channels would seem particularly beneficial for the northern area (i.e., Sites 1 through 3).

Of the four sites investigated, Site 1 is best suited to handle land drainage and sedimentary inputs expected to accompany flooding. This conclusion is based on the absence of a reef or shallow platform and the predominance of soft bottom offshore. However, this appraisal is subject to consideration of the movement of turbid water out of the immediate area of Site 1, which is at present unknown. Suspended sediments might move in the direction of Palalau, or offshore and into deeper water, or onto the reef flat to the southeast.

SUMMARY

1. Biological observations, water quality measurements, and sediment analyses were undertaken at four sites along the Kihei coast of east Maui. These sites were located at the shoreline in the immediate vicinity of: (1) Waiakoa Gulch; (2) Waipuilani Gulch (and Kalepolepo); (3) Kalama Park; and (4) Keawakapu Beach Park (Inoaole Gulch).
2. Two bathymetric configurations are present along this coast. Sites 2 and 3 represent an area with a shallow reef flat offshore. Sites 1 and 4 represent areas where the bottom slopes steadily into deep water from the shoreline.
3. Neither erosion channels nor deltaic deposits are clearly evident immediately offshore any of the four sites. Exposed, rounded basalt boulders on sand bottom fronting Waiakoa Gulch (Site 1) and a low, submarine mound of reef sand fronting the drainage culvert at Kalama Park may represent effects of land drainage. Because all stream channels along the Kihei coast were dry (normal for summer) no direct effects of flood discharge were evident.
4. Nutrient concentrations in nearshore waters (within 100 meters of the shoreline) were high at all four sites, and essentially non-limiting to phytoplankton growth. Total inorganic-nitrogen varied the most between sites, with the highest value (5.87 ug-at N/1) at Site 2. The concentration at Site 1 was also found to be high (3.11 ug-at N/1), and ground water inputs are the suspected source of this dissolved inorganic nitrogen.
5. Turbidity values were high at all sites, although particularly so at Sites 2 and 3, where wind waves maintain silt and clay particles in suspension over the shallow reef flat.
6. Most of the sediment samples collected offshore and from the beaches were fine-grained and well-sorted. Beach sediments showed evidence of the removal of very fine sand and silt fractions by wind (deflation).
7. The analysis of calcium carbonate content in offshore sediment samples

demonstrates a division between north-Kihei (essentially Sites 1 and 2) and south-Kihei (Sites 3 and 4) sediments. North-Kihei sediments contain generally less than 70% calcium carbonate by weight, whereas south-Kihei sediments contain 80% or more calcium carbonate by weight. Beach sands from Sites 1 and 2 were found to contain more than 70% calcium carbonate by weight, suggesting deflation is removing a predominantly terrigenous, very fine sand and/or silt fraction.

8. Live corals were not found at Site 1, where sand bottom predominates. Scattered coral heads occur between 50 and 100 meters out from the beach at Sites 2 and 3, although these do not represent healthy coral communities. Few fishes were observed at these three sites. A diverse assemblage of algae is present on the reef flat at Site 3 (Kalama Park), and edible species are harvested by local residents.

9. The nearshore benthic communities on the reef flat extending from Kalepolepo to Kalama Park appears stressed as a consequence of high turbidity characteristic of this area. This stress is manifested in a low diversity of fishes and macro-invertebrates. Turbid water may have biased observations at these sites, and evidence presented suggests that, in fact, biotic diversity is higher at Site 3 than at Site 2.

10. The source of suspended sediments at Sites 2 and 3 was not identified. This material may represent material discharged from streams (detrital origin), wind-blown into Maalaea Bay from central Maui (the Kealia Floodplain), or generated locally on the reef flat. Differences in the percent carbonate of sediments from each site, despite similar grain size characteristics, complicate establishing origin on the basis of existing data.

11. A healthy coral community, with a diverse fauna of reef fishes and echinoderms, is present on a basalt spur adjacent to the mouth of Iaoaole Gulch (Site 4). This marine community is typical of nearshore hard bottom areas from Keawakapu to Makena.

12. Construction of culverts would not destroy unique or valuable aquatic resources along existing stream courses on the Kihei Floodplain. These courses (gullies) are intermittantly dry and generally without indigenous aquatic biota.
13. The fauna observed in several ponds behind beach berms at Sites 1, 2, and 3 were inhabited by exotics (poeciliid fish, *Bufo marinus*) and mullet.
14. Neither the construction of culverts nor their effluents are expected to adversely affect nearshore marine communities in the vicinity of Sites 1, 2, or 3. These areas are presently subjected to intermittant land drainage. However, in the long term, stream channelization may increase sediment loads in nearshore areas, contributing to further degradation of the reef flat environment.
15. Discharge of terrigenous sediments during stream flow could be reduced by constructing settling ponds in conjunction with stream channelization. This procedure could improve present water quality in the nearshore environment, although the degree of benefit cannot be determined without a clearer understanding of sediment sources.
16. Adverse effects of stream effluent on the coral reef community off Inoaole Gulch (Site 4) could be mitigated by placing the channel outlet farther to the north of the basalt spur.
17. Of the four sites investigated, Site 1 is best suited to receive silt-laden effluents with minimal adverse effects, because of relatively deep water near shore and the predominance of sand bottom. However, consideration must be given to the movement of turbid water out of the immediate area.
18. Additional studies to determine the movement of fine sedimentary material from points of origin to deposition are recommended. These studies would be required to assess the long term impact of anticipated increases in sediment loads on water quality and biological communities in Maalaea Bay.

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Appendix A: Turbidity data for water samples from Kihei, Maui, August 20-21, 1977.

Site	Location	Date	Time	Distance from Shore (m)	Rep.	FTU	$\bar{x}$
Morning Samples - Light Wind Conditions < 10 mph							
1	Waiakoa Gulch	8/21	0705	50	1	0.29	
					2	0.29	0.29
				100	1	0.42	
					2	0.58	0.50
2		8/21	0805	50	1	1.17	
					2	1.21	1.19
				100	1	1.00	
					2	0.88	0.94
3	Kalama Park	8/21	0730	50	1	1.33	
					2	1.58	1.46
				100	1	1.13	
					2	1.17	1.15
4	Keawakapu	8/20	0820	50	1	0.33	
					2	0.42	0.38
				100	1	0.33	
					2	0.29	0.31
Afternoon Samples - Strong Wind Conditions > 10 mph							
1	Waiakoa Gulch	8/20	1350	50	1	0.25	
					2	0.50	0.38
				100	1	0.21	
					2	0.29	0.25
2		8/20	1505	50	1	0.58	
					2	0.67	0.63
				100	1	0.58	
					2	0.63	0.61
3	Kalama Park	8/20	1055	50	1	2.58	
					2	3.08	2.83
				100	1	1.50	
					2	1.08	1.29
4	Keawakapu	8/20	1540	50	1	0.29	
					2	0.29	0.29
				100	1	0.25	
					2	0.29	0.27

Appendix B: Nutrient data for water samples from Kihei, Maui, August 20-21, 1977.

Site	Date	Time	Rep.	NH_3-N (ug-at/l)	NO_2+NO_3-N (ug-at/l)	PO_4-P (ug-at/l)
1	8/21	0710	1	0.67	2.61	0.14
			2	0.24	2.68	0.15
2	8/21	0810	1	0.49	5.06	0.24
			2	0.42	5.75	0.29
3	8/21	0735	1	0.29	0.52	0.09
			2	0.50	0.54	0.13
4	8/20	1545	1	0.49	0.44	0.16
			2	0.25	0.33	0.13
detection limit				0.20	0.02	0.03

Appendix C: Dry weight in grams of sediment size grades in samples collected from the Kihei, Maui area.

Sample	Fine Gravel -3.0 Ø	-2.0 Ø	-1.0 Ø	Coarse Sand 0.0 Ø	1.0 Ø	Medium Sand 2.0 Ø	Fine Sand 3.0 Ø	Very Fine Sand and Silt Pan
1	-	-	-	0.01	0.12	4.90	254.94	48.21
2	-	0.17	0.56	1.72	4.48	12.80	193.92	91.22
3	-	-	0.07	0.23	0.92	18.42	252.25	35.86
4	-	-	-	0.17	4.72	145.32	195.43	4.79
5	-	-	-	0.04	1.23	22.02	308.80	9.21
6	-	0.13	1.04	0.67	0.46	2.84	208.62	46.91
7	-	0.05	0.02	0.11	1.25	96.80	255.93	7.78
8	-	0.83	7.26	12.97	19.28	31.59	190.06	32.76
9	0.13	0.04	0.08	0.19	0.55	43.98	267.92	7.44
10	-	-	0.21	0.63	2.65	28.28	279.14	10.90
11	-	-	0.05	0.83	1.62	3.32	82.54	179.68
12	-	0.19	1.67	5.50	11.58	34.57	249.07	38.54
13	-	0.36	2.14	1.30	0.23	0.36	111.95	168.50
14	-	0.91	13.18	46.92	97.44	66.53	28.83	69.23
15	-	0.40	3.16	7.96	8.35	6.02	36.28	248.72
16	-	0.44	0.46	0.84	3.98	20.92	168.03	127.00
17	-	0.27	0.59	2.82	27.50	87.14	211.47	29.57
18	-	-	0.01	0.06	0.24	1.20	112.49	197.09
19	-	-	0.02	0.11	0.27	3.72	78.56	194.14
20	-	-	-	$<$ 0.01	0.05	1.12	206.73	102.50

Appendix D: Percent calcium carbonate in sediment samples.

Sample Number	Replicate 1	Replicate 2	$\bar{x}$	S.D.
1	80.1	80.9	80.5	0.6
2	80.1	79.4	79.8	0.5
3	83.9	83.9	83.9	0.0
4	88.3	85.3	86.8	2.1
5	89.1	88.3	88.7	0.6
6	79.4	80.1	79.8	0.5
7	84.6	83.9	84.2	0.5
8	83.9	84.6	84.2	0.5
9	82.4	83.9	83.1	1.1
10	86.1	87.6	86.9	1.1
11	62.3	61.6	62.0	0.5
12	75.7	75.0	75.3	0.5
13	53.4	55.7	54.5	1.6
14	80.9	80.9	80.9	0.0
15	55.7	57.1	56.4	1.0
16	60.1	61.6	60.9	1.1
17	73.5	72.7	73.1	0.6
18	54.2	55.7	54.9	1.1
19	55.7	57.1	56.4	1.0
20	72.0	70.1	71.2	1.3

Appendix E. Taxonomic listing of marine organisms observed or collected in the Kihei area (Maui) during August, 1977.

Species	Site
ALGAE	
CYANOPHYTA	
Fam. Oscillatoriacea	
Lyngbya sp.	2
CHLOROPHYTA	
Fam. Ulvaceae	
Enteromorpha sp.	3
Ulva fasciata Delile	2,3
Ulva reticulata Forsskal	
Fam. Dasycladaceae	
Neomeris sp.	2
PHAEOPHYTA	
Fam. Dictyotaceae	
Dictyopteris plagiogramma (Montagne) Vickers	3
Dictyota acutiloba J. Agradh	
Dictyota crenulata J. Agardh	3
Padina crassa Yamada	3
Fam. Sargassacea	
Sargassum echinocarpum J. Agardh	3
RHODOPHYTA	
Fam. Gelidiaceae	
Pterocladia capillacea (Gmelin) Bornet	2
Pterocladia caerulescens Kutzing	2
Fam. Corallinaceae	
Amphiroa sp.	3
Corallina sp.	3
Jania capillaceae Harvey	3
Jania sp.	3
Fam. Cryptonemiaceae	
Grateloupia filicina (Wulfen) C. Agardh	2,3
Grateloupia hawaiiensis Dawson	2
Fam. Hypneaceae	
Hypnea cervicornis J. Agardh	3
Hypnea sp.	3
Fam. Gracilariacea	
Gracilaria coronopifolia J. Agardh	2,3
Fam. Phyllophoracea	
Ahnfeltia concinna J. Agardh	1,2,4

Appendix E. (Continued)

Species	Site
Fam. Ceramiaceae	
Ceramium sp.	2
Fam. Rhodomelaceae	
Acanthophora spicifera (Vahl) Boerg.	3
Laurencia nidifica J. Agardh	3
Laurencia succisa Cribb	3
Polysiphonia hawaiiensis Hollenberg	2,3
INVERTEBRATES	
CNIDARIA	
unidentified, small anemone	1
Fam. Pennariidae	
Halocordyle disticha (Goldfuss)	1,4
Fam. Alcyoniidae	
Anthelia edmondsoni (Verrill)	2
Fam. Seriatoporidae	
Pocillopora damicornis (L.)	2,3
Pocillopora meandrina Dana	3,4
Fam. Acroporidae	
Montipora verrucosa (Lam.)	4
Montipora patula Verrill	4
Montipora flabellata Studer	4
Montipora verrilli Vaughan	4
Fam. Poritidae	
Porites compressa Dana	3,4
Porites lobata Dana	2,3,4
Porites evermanni Vaughan	2,3,4
Fam. Orbicellidae	
Leptastrea purpurea Dana	4
Fam. Zoanthidae (soft corals)	
Palythoa tuberculosa (Esper) Klunzinger	2,4
Zoanthus pacificus Walsh and Bowers	2
POLYCHAETA	
Fam. Eunicidae	
Eunice (*Nicidion*) sp.	3si
Fam. Capitellidae	
Capitella sp.	3si
Fam. Magelonidae	
	3si

Appendix E. (Continued)

Species	Site
Fam. Cirratulidae	
Cirratulus sp.	3si
ARTHROPODA	
Fam. Calappidae	
Calappa sp.	3
Fam. Portunidae	
Thalamita edwardsi Borradaile	3
Portunus pubescens (Dana)	3
MOLLUSCA	
Fam. Cypraeidae	
Cypraea maculifera Schilder	4
Fam. Mytilidae	
Hormomya crebristriatus (Conrad)	1,2
ECTOPROCTA	
Fam. Schizoporellidae	
Schizoporella unicornis (Johnston)	1
ECHINODERMATA	
Fam. Asterinidae	
Asterina anomala Clark	3
Fam. Amphiuridae	
Amphipholis squamata (Della Chiaje)	3
Fam. Ophiocomidae	
Ophiocoma sp.	3
Fam. Diadematidae	
Echinothrix calamaris (Pallas)	1,4
Echinothrix diadema (Linn.)	2,3,4
Fam. Echinometridae	
Echinometra mathaei (Blainville)	2,4
Echinometra mathaei oblonga (Blainville)	2,4
Heterocentrotus mammillatus (Linn.)	4
Fam. Toxopneustidae	
Tripneustes gratilla (Linn.)	1,2,4
Fam. Holothuridae	
Actinopyga mauritiana (Quoy & Gaimard)	4

Appendix E. (Continued)

Species	Site
FISHES	
CHORDATA	
Fam. Chanidae	
Chanos chanos (Forskal)	4
Fam. Mugilidae	
Mugil cephalus Linn.	1 (pond)
Fam. Fistulariidae	
Fistularia petimba Lacepede	4
Fam. Carangidae	
Decapterus macarellus	1,4
Carangoides sp.	4
Fam. Lutjanidae	
Lutjanus kasmira	1
Fam. Mullidae	
Parupeneus porphyreus Jenkins	4
Parapeneus multifasciatus (Quoy & Gaimard)	4
Parapeneus pleurostigma (Bennett)	4
Fam. Chaetodontidae	
Chaetodon lunula (Lacepede)	4
Chaetodon miliaris Quoy & Gaimard	1,3,4
Chaetodon trifasciatus Mungo Park	4
Chaetodon sp.	3
Fam. Cirrhitidae	
Paracirrhites forsteri (Bloch & Schneider)	4
Fam. Pomacentridae	
Dascyllus albisella Gill	1,3
Abudefduf abdominalis (Quoy & Gaimard)	1,2,3,4
Chromis vanderbilti (Fowler)	4
Pomacentrus jenkinsi Jordan & Evermann	4
Fam. Labridae	
Thalassoma duperreyi (Quoy & Gaimard)	3,4
Fam. Zanclidae	
Zanclus canescens (Linn.)	4
Fam. Acanthuridae	
Acanthurus nigrofuscus (Forskal)	4
Acanthurus triostegis sandvicensis Streets	1,2,3
Acanthurus dussumieri Cuvier & Valenc.	4
Naso unicornis (Forskal)	4
Acanthurus sp.	1

Appendix E. (Continued)

Species	Site
Fam. Balistidae	
Rhinecanthus rectangulus (Bloch & Schneider)	4
Melichthys vidua (Solander)	4
Fam. Canthigasteridae	
Canthigaster jactator (Jenkins)	4